EXPERIMENTER TO PLANETARY SCIENCE ARCHIVE INTERFACE CONTROL DOCUMENT (EAICD)
FOR THE
MEX-MARSIS ACTIVE IONOSPHERIC SOUNDING (AIS) LEVEL 2 DATA

ISSUE 1.1

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Distribution List

Recipient	Organisation

Change Log

Date	Sections Changed	Reasons for Change
04-18-08	all	General revision for initial AIS data release

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1 INTRODUCTION

<u>Special Note</u>: Thie EAICD relates to a subset of the overall data produced by the MARSIS experiment. Specifically, this document deals only with the MARSIS Active Ionospheric Sounding (AIS) data, which is generated via an instrument mode exclusive of the instrument subsurface-sounding modes of operation. Although this AIS-specific EAICD is intended to focus very narrowly on describing the AIS data, it draws heavily, in terms of both format and content, on the MARSIS EAICD prepared at an earlier date by Roberto Orosei , Anton Ivanov, and other members of the MARSIS team.

1.1 PURPOSE AND SCOPE

The purpose of this EAICD (Experimenter to Archive Interface Control Document) is to provide users of the MARSIS Level 2 AIS data, and also the project archiving authority, with a detailed description of the product.

1.2 ARCHIVING AUTHORITIES

The Planetary Data System (PDS) Standard is used as the archiving standard by NASA for U.S. planetary missions, and has, in large part, been adopted by the ESA Planetary Data Archive (PSA). Mars Express data are archived to the PSA by individual Principal Investigator groups, and archived data volumes must comply with PSA standards.

1.3 CONTENTS

This document describes how Active Ionospheric Sounding (AIS) data from the MARSIS instrument are prepared for archiving at the ESA PSA in PDS-compliant form. It includes information on how data were processed, formatted, labelled and uniquely identified. The document discusses general naming schemes for data volumes, data sets, data and label files. Standards used to generate the product are explained. Software that may be used to access the product is explained. The design of the data set structure and the data product is given. Examples of these and further explanatory material are given in the appendices.

1.4 INTENDED READERSHIP

The intended audience include members of the archiving authority (Planetary Data System for NASA and Planetary Science Archive for ESA) design team and any potential user of the MARSIS data.

1.5 APPLICABLE DOCUMENTS

[AD01] MARSIS Flight User Manual, Issue 3, INFOCOM ID-MAR-0008-INF, 18 December 2003
[AD02] MARSIS DES Operation Sequence Table, Issue 1, LABEN TL 19392, 29 January 2003
[AD03] MARSIS DES Parameters Table, Issue 3, LABEN TL 18546
[AD04] MARSIS Packet Structure Definition, Issue 6, LABEN TL 16927, 3 February 2003
[AD05] Mars Exploration Rover Project Planetary Constants and Models, Version 2, JPL IOM 312.F-02-003, 4 October 2002
[AD06] Mars Express Archive Generation, Validation and Transfer Plan, Revision 1.0, ESA-MEX-TN-4009, 21 June 2001

[AD07] Mars Express Auxiliary Data Conversion into SPICE Kernels and Distribution, Issue 1.0, MEX-EST-PL-10210, 20 September 2002
[AD08] Mars Express Master Science Plan, Draft 1.0, MEX-EST-PL-11912, 12 May 2003
[AD09] Planetary Data System Data Preparation Workbook, Version 3.1, JPL D-7669, Part 1, 17 February 1995
[AD10] Planetary Data System Standards Reference, Version 3.7, JPL D-7669, Part 2, 20 March 2006
[AD11] Planetary Science Data Dictionary, Revision D, JPL D-7116, 15 July 1996
[AD12] Planetary Science Archive - Experiment Data Release Concept, Issue 1.16, SOP-RSSD-TN-015, 12 May 2005
[AD13] Planetary Science Archive - Non-PDS compliant keyword Usage, Draft 2, SOP-RSSD-PL-XXXX, 2 April 2002
[AD14] Planetary Science Archive - Required Keywords, Issue 1.4, SOP-RSSD-LI-004, 27 January 2004
[AD15] Planetary Science Data Archive Technical Note - Geometry and Position Information, Issue 3, Revision 4, SOP-RSSD-TN-010, 9 November 2004

The following example list of references directs the data user to additional information regarding the derivation and interpretation of ionospheric parameters from the MARSIS ionospheric data. These publications are freely available professional publications, and are not included as part of this archive.

Radar Soundings of the Ionosphere of Mars, D. A. GURNETT, D. L. KIRCHNER, R. L. HUFF, D. D. MORGAN, A. M. PERSOON, T. F. AVERKAMP, F. DURU, E. NIELSEN, A. SAFAEINILI, J. J. PLAUT, and G. PICARDI, *Science, 310*, 1929-1933, Dec. 23, 2005. (

Solar Control of Radar Wave Absorption by the Martian Ionosphere, D. D. MORGAN, D. A. GURNETT, D. L. KIRCHNER, R. L. HUFF, D. A. BRAIN, W. V. BOYNTON, M. H. ACUNA, J. J. PLAUT, and G. PICARDI, *Geophys. Res. Lett., 33,* L13202, doi:10.1029/2006GL026637. July 13, 2006.

Magnetically Controlled Structures in the Ionosphere of Mars, F. DURU, D.A. GURNETT, T.F. AVERKAMP, D.L. KIRCHNER, R.L. HUFF, A.M. PERSOON, J.J. PLAUT, and G. PICARDI, *J. Geophys. Res., 111*, A12204, doi:10.1029/2006JA011975, Dec. 6, 2006.

Observations of Vertical Reflections from the Topside Martian Ionosphere E. NIELSEN, H. ZHOU, D.A. GURNETT, D.L. KIRCHNER, D.D. MORGAN, R. Huff, R. OROSEI, A. SAFAEINILI, J.J. PLAUT, and G. PICARDI, *Space Science Reviews, 126*, No. 1-4, pp. 373-388, doi:10.1007/s11214-006-9113-y, October 2006. (available online December 19, 2006)

Vertical Sheets of Dense Plasma in the Topside Martian Ionosphere, E. NIELSEN, X.-D. WANG, D.A. GURNETT, D.L. KIRCHNER, R.L. HUFF, R. OROSEI, A. SAFAEINILI, J.J. PLAUT, and G. PICARDI, *J. Geophys. Res., 112*, E02003, doi:10.1029/2006je002723, Feb. 14, 2007.

Local Plasma Processes and Enhanced Electron Densities in the Lower Ionosphere in Magnetic Cusp Regions on Mars, E. NIELSEN, M. FRAENZ, H. ZOU, J.-S. WANG, D.A. GURNETT, D.L. KIRCHNER, D.D. MORGAN, R. HUFF, A. SAFAEINILI, J.J. PLAUT, G. PICARDI, J.D. WINNINGHAM, and R.A. FRAHM, and R. LUNDIN *Planetary and Space Science, 55,* No. 14, doi:10.1016/j.pss.2007.07.003, pp. 2164-2172, November 7, 2007.

An Overview of Radar Soundings of the Martian Ionosphere from the Mars Express Spacecraft, D.A. GURNETT, R.L. HUFF, D.D. MORGAN, A.M. PERSOON, T.F. AVERKAMP, D.L. KIRCHNER, F. DURU, F. AKALIN, A.J. KOPF, E. NIELSEN, A. SAFAEINILI, J.J. PLAUT, and G. PICARDI, *Adv. Space Research*, doi:10.1016/j.asr.2007.01.062, in press, Jan. 2007.

Electron Densities in the Upper Ionosphere of Mars from the Excitation of Electron Plasma Oscillations, F. DURU, D.A. GURNETT, D.D. MORGAN, R. MODOLO, A.F. NAGY, and D. NAJIB, *J. Geophys. Res.*, in press, Feb. 25, 2008.

Variation of Mars' Ionospheric Electron Density from Mars Express Radar Soundings, D.D. MORGAN, D.A. GURNETT, D.L. KIRCHNER, J.L. FOX, E. NIELSEN, J.J. PLAUT, and G. PICARDI, *J. Geophys. Res.*, submitted, December 2007.

1.6 RELATIONSHIPS TO OTHER INTERFACES

Other interfaces that have an impact on MARSIS data set generation, packaging, distribution, and documentation include:

- MARSIS calibration data/software: reprocessing of calibration data or a change to the software may have a direct impact on the generation of the data sets.
- Release Concept: Changes would directly impact data set generation, packaging, distribution, and documentation.
- PSA Archive Delivery Requirements: Any delivery requirement changes will directly impact the MARSIS datasets.
- SPICE Data: Changes to these data will affect any geometry files delivered
- Geolib and SPICE Software Libraries: As above, and also for the GEO_MARS.* index files.
- PVV Software: Changes to this validation software could force changes to labels or data sets.

1.7 ACRONYMS AND ABBREVIATIONS

ACQ Acquisition phase
AIS Active Ionosphere Sounding mode
ASDC ASI Science Data Centre
ASI Agenzia Spaziale Italiana (Italian Space Agency)
CAL Calibration mode
CD-ROM Compact Disk - Read Only Memory
CMP Compressed data
DCG Digital Chirp Generator
DVD Digital Versatile Disk
EAICD Experimenter to Planetary Science Archive Interface Control Document
ESA European Space Agency
ESOC European Space Operation Centre
ESTEC European Space Technology Centre
FFT Fast Fourier Transform
IND Individual Echoes
LOL Loss of Lock
MARSIS Mars Advanced Radar for Subsurface and Ionosphere Sounding
MEX Mars Express
NPM Noise Power Measurement
OST Operation Sequence Table
PSA Planetary Science Archive
PT Parameter Table
RAW Raw data
RXO Receive Only mode
S/C Spacecraft
SCET Spacecraft Elapsed Time
SS1-SS5 Subsurface Sounding modes 1-5
TC Telecommand
TM Telemetry
TRK Tracking phase
UNC Uncompressed data

1.8 CONTACT NAMES AND ADDRESSES

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2 OVERVIEW OF INSTRUMENT DESIGN, DATA HANDLING PROCESS AND PRODUCT GENERATION

2.1 SCIENTIFIC OBJECTIVES

The primary objective of MARSIS is to map the distribution of water, both liquid and solid, in the upper portions of the crust of Mars. Detection of such reservoirs of water will address key issues in the hydrologic, geologic, climatic and possible biologic evolution of Mars.

The scope of this document addresses only the secondary objective of using MARSIS as an ionosphere sounder to characterize the interactions of the solar wind with the ionosphere and upper atmosphere of Mars. Radar studies of the ionosphere will allow:

- global measurements of the ionosphere electron density,
- investigation of the influence of the Sun and the solar wind on the electron density.

Note: Ionospheric parameters may also be derived from the MARSIS sub-surface data. An example reference is FIRST ESTIMATION OF TOTAL ELECTRON CONTENT OF MARS IONOSPHERE A. Safaeinili1,W. Kofman2, J. Mouginot2 J. Plaut1, Giovanni Picardi3,1Jet Propulsion Laboratory, Pasadena, 91109, USA. 2Labratoire de Planetologie de Grenoble, CNRS/UJF, France, 3Dipartimento INFOCOM, University of Rome La Sapienza", Rome 00184, Italy

2.2 INSTRUMENT DESCRIPTION

MARSIS is a multi-frequency nadir-looking pulse-limited radar sounder and altimeter, which uses synthetic aperture techniques. MARSIS also has the capability to operate as a topside ionospheric sounder. MARSIS can be effectively operated at any altitude lower than 800 km in subsurface sounding mode, and below ~1200 km in ionosphere sounding mode. The instrument consists of two antenna assemblies and an electronics assembly. Maximum penetration depths are achieved at the lowest frequencies, and penetration will be in the order of a few kilometres, depending on the nature of the material being sounded. On the dayside of Mars, the solar wind-induced ionosphere does not allow subsurface sounding at frequencies below approximately 3.5 MHz, as the signal would be reflected back at the radar without reaching the surface. To achieve greater subsurface probing depths, operations on the night side of Mars are thus strongly preferred.

For subsurface sounding, a “chirp” signal will be generated and transmitted at each operating frequency for a period of about 250 microseconds. The instrument then switches to a receive mode and records the echoes from the surface and subsurface. The total transmit-receive cycle lasts a few milliseconds, depending on altitude. The received signals are passed to a digital-to-analogue converter and compressed in range and azimuth. The azimuth integration accumulates a few seconds of data and results in an along-track footprint size of 10 km. The cross-track footprint size is on the order of 20 km. Digital on-board processing greatly reduces the output data rate to 75 kilobits per second or less. For each along-track footprint, echo profiles will show the received power as a function of time delay, with a depth resolution of 50-100 m, depending on the wave propagation speed in the crust.

Active ionosphere sounding consists of transmitting a pulse from MARSIS at a frequency f, and then measuring the intensity of the reflected radar echo as a function of time delay. For a radar signal incident on a horizontally stratified ionosphere, a strong specular reflection occurs from the level where the wave frequency is equal to the electron plasma frequency. By measuring the time delay for the reflected signal (controlled by the group delay), the plasma frequency, and therefore the electron density can be derived as a function of height. The frequency of the transmitted pulse is systematically stepped to yield time delay as a function of frequency.

2.2.1 ANTENNAS

MARSIS antenna assembly consists of two antennas, a dipole and a monopole. The primary dipole antenna, parallel to the surface and to the direction of spacecraft motion, is used for transmission of pulses and for reception of pulse echoes reflected by the Martian surface, subsurface and ionosphere. The secondary monopole antenna, oriented along the nadir direction, is designed to reduce clutter when MARSIS operates in subsurface sounding mode.

2.2.2 FREQUENCIES

MARSIS is an ultra-wideband radar sounder capable of transmitting at frequencies ranging from approximately 10 kHz up to 5.5 MHz. For subsurface sounding, the transmitted signal has a 1 MHz bandwidth, centred at either 1.8 MHz, 3 MHz, 4 MHz or 5 MHz. For ionosphere sounding, transmission frequencies will range from about 10 KHz to 5.5. MHz, with a transmitted bandwidth of 10.937 kHz and an identical frequency granularity.

2.2.3 TRANSMITTED WAVEFORMS

For active ionosphere sounding, the transmitted waveform is simply a short pulse at a constant frequency, resulting in an almost monochromatic tone.

2.3 ON-BOARD PROCESSING

Active Ionospheric Sounding (AIS) consists of a single mode of operation. A discrete frequency is transmitted, then the onboard software utilizes a Discrete Fourier Transform (DFT) to calculate the received power. This operation is then repeated over 160 different frequency steps to acquire and construct a single AIS data frame.

2.3.1 DATA COMPRESSION

Prior to transmission of the AIS data to the ground, the data are compressed by normalizing with respect to the largest detected value in the frame.

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2.4 INSTRUMENT OPERATION

MARSIS has been designed to perform subsurface sounding at each orbit when the altitude is below 800 Km. A highly eccentric orbit such as the baseline orbit places the spacecraft within 800 km from the surface for a period of about 26 minutes. This would allow mapping of about 100 degrees of arc on the surface of Mars each orbit, allowing extensive coverage at all latitudes within the nominal mission duration. To achieve this global coverage MARSIS has been designed to support both day side and night side operations, although performances are maximized during night time (solar zenith angle >80°), when the ionosphere plasma frequency drops off significantly and the lower frequency bands, which have greater subsurface penetration capability, can be used.

Active Ionosphere Sounding will be carried out by MARSIS at certain passes when the spacecraft is below ~1200 Km of altitude, both during day and night time. Each active ionosphere sounding observation consists in transmitting and receiving echoes from 160 short, narrow-banded pulses at different frequencies. When a pulse reaches the layer in the ionosphere where the plasma frequency is equal to its frequency, it is reflected back at the radar. Because the detailed variation of the plasma frequency in the ionosphere is unknown, the time delay of each echo cannot be predicted, and it is thus necessary to have an extremely long receiving window to ensure that useful data are collected. The receive window is divided into 80 segments, each of which is as long as the transmitted pulse: power received within each segment is computed, and the result is stored for down-link. Due to resource limitations, it is necessary to transfer ionosphere data from MARSIS to the spacecraft mass memory over a time span six times longer than the one used for their acquisition.

The MARSIS instrument is commanded by means of two tables, the Operations Sequence Table and the Parameters Table, which are up-linked from the ground as part of the instrument programming and commanding, and loaded into instrument memory at switch-on.

2.5 DATA HANDLING PROCESS

MARSIS L1 data are routinely acquired at Iowa via the following process:

1) MARSIS telemetry data (Level 1) are retrieved from the ESOC-based Mars Express DDS by personnel at the ASI Science Data Center (ASDC) located in Frascati, Italy.
2) All MARSIS L1 data are transferred to Iowa via a one-way data mirror established between Iowa and ASDC. At 1-hour intervals the mirroring function (a Unix rsync-based script) on the Iowa MARSIS secure server locates any new MARSIS files on the ASDC server and creates copies at Iowa
3) AIS L1 data are extracted at Iowa, then processed into PSA/PDS-compliant Level 2 formats

2.6 PRODUCT GENERATION AND UTILIZATION

MARSIS AIS Level 2 (L2) data products are routinely produced at Iowa via the following process

1) The AIS L2 data products are generated automatically within ~15 minutes of receipt of Level 1 data at Iowa.
2) The L2 AIS data are then organized into a single online volume (super-volume) that is available to the MARSIS team at all times. All of the files contained in the super-volume are in PDS/PSA compliant format.
3) The same AIS super-volume used by the MARSIS team for scientific analysis is also used to produce incremental volume releases for submission to PSA.

2.6.1 INSTRUMENT CALIBRATIONS

The AIS Level 2 data are fully calibrated, with measurements expressed in units of electric field spectral density. Instrument calibrations were performed, and refined over time, as part of the hardware development and test phases.   The following provides a summary of how calibration data are applied to raw AIS data values to yield values expressed in scientific units.

The MARSIS AIS telemetry is transmitted to the ground in a compressed format. The first step in calibration is to decompress the data. Next, a given measured number is converted to the power that appears at the input to the A/D converter in the MARSIS receiver. Finally, this power measurement is converted to the equivalent power at the antenna via a system gain lookup table, where a final measured value is given in units of electric field spectral density (V*V / m*m / Hz). The calibration look-up table values are frequency dependent. The table is included in Appendix C.

<u>AIS Level 2 Data Calibration Summary</u>

Step 1: Decompress the level 1A data.

Step 2: Transform the data to power expresses in the units of dBm.

$$10*\log((X(1.26/(128*255))^2)/0.1) + 5.4$$

where X is the decompressed data value

Step 3: Convert power to the antenna by correcting for system gain. The system gain is frequency dependent and data are corrected for variations in system gain over frequency via a lookup table

Step 4: Divide by the bandwidth (10.9KHz) and antenna length squared; $(20m)^2$

Example:
Raw S/C Telemetry Data →
Decompress data →
decompressed data value = $6.984*10^5$ →
data value expressed in dBm = $10*\log((X(1.26/(128*256))^2)/0.1) + 5.4$ →
power at A/D converter = -14.445dBm →
correct for system gain via the lookup table = 68dB →
power on the antenna is -82dBm →
transform value in dBm to Vrms squared →
value in dBm=$\log10(V^2/50/1mW)$ → 315.47E-12 V^2 →
divide by antenna length squared $(20.0meters)^2$ →
giving a value of 788.69E-15 →
divide by bandwidth (10.9KHz) → final value in units of electric field spectral density = $788.69E^{-15}\ V^2/m^2/Hz$ (This is the value that would be stored in the AIS Level 2 binary data file; FRM_AIS_RDR_xxxx.DAT)

2.6.2 Software

There are four basic ways a user may access the AIS data set.

1) Use standard tools provided in Unix/Linux/MacOsX operating systems (od, awk, etc.)
2) Compile the included C source software provided in the SOFTWARE directory. This software is intended to be compatible with Windows, Unix, Linux, and MaxOsX
3) The user may use the Java-based tool provided in the SOFTWARE directory. Please be aware that this tool and the supporting documentation are under development and will not be available in the first deliveries.
4) The user may elect to write his or her own custom software to analyze or display the AIS L2 data

The fundamental AIS L2 data file is provided in binary file format. The binary format was chosen to optimize data processing speed and minimize disk storage space. Provided in the SOFTWARE directory is an example program which will convert the binary data file to human readable ascii text. Many commercially available programs will accept ASCII text input (Star Office, IDL, Microsoft Excel, etc).

In addition, the archive was arranged to be aligned on 32 bit boundaries. Naturally aligned floating point numbers are easily converted to ASCII with standard Unix tools (such as od). Under Unix, issuing the command

```
od -f FILENAME
```

will convert the binary file to floating point number. The headers in the data files are not stored as binary data, so these may be ignored. (Note that IEEE floating point values are stored most significant byte first).

The Java-based display tool referred to in item 3) above is based on a multi-project custom software package developed by the University of Iowa over many years. The stand-alone version to be supplied as part of the AIS archive will allow the user to display overview spectrograms, ionograms, and a variety of line plots, with very flexible control of axis scaling, color bars, etc. The Java-based tool and supporting documentation to be archived are in final development and will be included as part of an upcoming AIS data release during the current calendar year (2008).

N.B. The program NasaView (a standard PDS data product reader) is not compatible with AIS L2 data due to the AIS measured values being too small (<10exp-5). NasaView interprets these values as zeros. Please use the software included in the archive to read the data products.

3 ARCHIVE FORMAT AND CONTENT

This section describes the features of the MARSIS Standard Product Archive volumes, including the file names, file contents, and file types, which apply to all MARSIS data sets. Specialization of this information to each single data set is provided in Section 4.

3.1 FORMAT AND CONVENTIONS

3.1.1 DELIVERIES AND ARCHIVE VOLUME FORMAT

Delivery of AIS data to the PSA for archiving will be done according to the incremental data release concept described in [AD12].

The following are the required volume keywords (with AIS-specific example values):

```
VOLUME_SERIES_NAME      = "MISSION TO MARS"
VOLUME_SET_NAME         = "MARS EXPRESS MARSIS IONOSPHERE DATA"
VOLUME_SET_ID           = US_UIOW_DPA_MEXMDI_1000
VOLUME_NAME             = "VOLUME 1: MARS EXPRESS MARSIS IONOSPHERE DATA"
VOLUME_ID               = MEXMDI_1001
VOLUME_VERSION_ID       = "VERSION 1"
DATA_SET_ID             = "MEX-M-MARSIS-3-RDR-AIS-V1.0"
```

3.1.2 DATA SET ID FORMATION

The Data Set ID for the AIS volume is given as follows:

DATA_SET_ID = "MEX-M-MARSIS-3-RDR-AIS-V1.0"

where:

MEX	---	is the mission name designator for Mars Express
M	---	designator for planet Mars
MARSIS	---	indicates the instrument name (MARSIS radar sounder)
3	---	CODMAC data processing level
RDR	---	is the acronym for Reduced Data Record
AIS	---	is the acronym for Active Ionospheric Sounding
V1.0	---	indicates the volume release version number

The DATA_SET_ID given above is correct for the nominal mission only, which covers through 31 December 2005. DATA_SET_IDs for data acquired during mission extensions will carry a unique designator as follows:

DATA_SET_ID = "MEX-M-MARSIS-3-RDR-AIS-EXT1-V1.0" (for the first mission extension)

DATA_SET_ID = "MEX-M-MARSIS-3-RDR-AIS-EXT2-V1.0" (for the second mission extension)

and so on.

3.1.3 DATA DIRECTORY NAMING CONVENTION

Because it is estimated that a large number of data files will be present on a data set, the directory containing them will be further divided into a number of subdirectories, each containing data collected over ten orbits. These subdirectories will be named so as to make clear which data products they contain and when such data were collected. Their names will be in the form **RDR123X** , where this directory contains AIS data covering orbits 1230 through 1239.

3.1.4 FILE NAMING CONVENTION

All data product files throughout different MARSIS data sets will be named using the same file naming convention. File names are built by a concatenation of three-letter components separated by underscore characters (“_”). Each component provides one type of information on the content of the file.

File extension defines the format of data contained in the file: the extension is usually “.DAT”, denoting that the file contains a binary table object (data objects are defined according to [AD10]).

The file naming conventions used for the AIS Level 2 data products are as follows:

FRM_AIS_RDR_xxxx.DAT

where:

FRM --- acronym for ‘frame’ (MARIS designation)
AIS --- is an acronym for Active Ionospheric Sounding
RDR --- is the acronym for Reduced Data Record
xxxx --- denotes the four-digit orbit number
DAT --- file extension indicating a binary table object

3.2 STANDARDS USED IN DATA PRODUCT GENERATION

3.2.1 PDS STANDARDS

All AIS Level 2 data products conform to PDS version 3.7.

3.2.2 TIME STANDARDS

3.2.2.1 START_TIME AND STOP_TIME FORMATION

The PDS formation rule for dates and time in UTC is: YYYY-MM-DDThh:mm:ss.fff or YYYY-DDDThh:mm:ss.fff, with

- YYYY year (0000-9999)
- MM month (01-12)

- DD day of month (01-31)
- DDD day of year (001-366)
- T date/time separator
- hh hour (00-23)
- mm minute (00-59)
- ss second (00-59)
- fff fractions of second (000-999) (restricted to 3 digits)

3.2.2.2 SC_CLOCK_START_COUNT AND SC_CLOCK_STOP_COUNT

The SC_CLOCK*COUNTS represents the on-board time counters (OBT) of the spacecraft and instrument computers. This OBT counter is given in the headers of the experiment telemetry source packets. It contains the data acquisition start time as 32 bit of unit seconds followed by 16 bit of fractional seconds. The time resolution of the fractional part is $2^{-16} = 1.52\times10^{-5}$ seconds. Thus the OBT is represented as a decimal real number in floating-point notation with 5 digits after the decimal point. A reset of the spacecraft clock is represented by an integer number followed by a slash, e.g. “1/” or “2/”.

Example: SPACECRAFT_CLOCK_START_COUNT = "1/21983325.39258"

3.2.3 REFERENCE SYSTEMS

The MARSIS AIS data are the instrument reference frame. In the AIS-specific GEOMETRY file, latitude and longitude values indicate the sub-satellite position. Longitude is given in positive-East coordinates in the range 0°-360°.

3.2.4 OTHER APPLICABLE STANDARDS

None.

3.3 DATA VALIDATION

AIS data volume content and structure are validated using the PSA-provided PVV tool. PVV checks syntax of file names, label content, and also confirms the basic volume structure.

Science validation of the AIS data product is accomplished as follows.

A formal validation of all new AIS data by the Iowa MARSIS Science Data Manager is performed on a weekly basis. This routine validation activity includes examination of processing logs generated by the automatic processing routines, examination of data products for correctness with respect to scheduled operations (data times, modes, etc.), and examination of data products for discernable processing errors. Results from the validation activities are routinely entered into the validation log.

Informal science validation is performed by MARSIS team scientists, who are encouraged to report any problems experienced in using the AIS L2 data (processing errors, usability problems, etc.). The Iowa MARSIS Science Data Manager logs and responds to any such reports.

3.4 CONTENT

3.4.1 VOLUME SET

The AIS Level 2 data volume is maintained electronically, and periodically updated through PSA's revision and release mechanism [AD12].

3.4.2 DATA SET

A diagram of the AIS volume structure is given below.

```
===========================================================================
Volume Contents and Structure
===========================================================================

[MEX-M-MARSIS-3-RDR-AIS-V1.0] (root directory)
   |
   |-AAREADME.TXT     Plain text describing volume contents,
   |                  organization, and its use.
   |
   |-ERRATA.TXT       Describes known deficiencies or caveats in the
   |                  data on this volume.
   |
   |-VOLDESC.CAT      High level description of volume contents.
   |
   |-[BROWSE]         Contains browse plots depicting the data.
   |    |
   |    |-[ACTIVE_IONOSPHERIC_SOUNDER]
   |                 |
   |                 |-[RDRxxxX]          Plots of the Active Ionospheric
   |                       |              Sounder Spectrograms for each
   |                       |              orbit.
   |                       |
   |                       |-[RDRxxxx]    Plots of each Ionogram in the
   |                                      orbit xxxx.
   |
   |
   |-[CATALOG]        Information about the Mars Express mission, spacecraft,
   |                  and Active Ionospheric Sounder (AIS) Instrument; lists
   |                  the cognizant personnel and references revelant
   |                  documentation.
   |
   |-[DATA]         Binary archived data from the Active Ionospheric
   |                Sounder instrument.
   |    |
   |    |-[ACTIVE_IONOSPHERIC_SOUNDER]
   |                 |
   |                 |-[RDRxxxX]          Data of the Active Ionospheric
   |                                      Sounder for each orbit.
   |
   |-[DOCUMENT]       Experiment to Archive Interface Control Document (EAICD),
                      instrument technical documentation, etc.
   |
   |-[SOFTWARE]       Software tools and support documentation for displaying the
                      Active Ionospheric data

   |-[EXTRAS]         Bonus content not necessarily conforming to archiving
   |                  standards.  Included are HTML files with thumbnails
   |                  to navigate the browse products.
```

```
|
|-[INDEX]          Volume and cumulative indices of archive products.
|
|-[LABEL]          Format descriptions of the archived data products.
```

3.4.3 *DIRECTORIES*

3.4.3.1 ROOT DIRECTORY

Files in this directory are as follows:

AAREADME.TXT	Volume content and format information
ERRATA.TXT	Cumulative listing of comments and updates concerning all MARSIS Data Products
VOLDESC.CAT	Description of the contents of the volume in PSA/PDS format

3.4.3.2 INDEX DIRECTORY

This directory contains indexes, that is files with information that allows a user to locate data of interest. Within the Planetary Science Archive (PSA), index files fulfill two more purposes. First, some index files are read by database software and allow the ingestion of additional parameters into the database. Secondly, the PSA is using the index files to check for correct deliveries of data set releases and revisions into the PSA. Indexes are written as INDEX_TABLE objects, that is a specific type of PDS ASCII TABLE objects, and are provided with detached PDS label files.

The files included in the MARSIS AIS INDEX directory, as required in [AD12], are:

INDXINFO.TXT	Text description of the directory contents
INDEX.LBL	Detached PDS label to describe INDEX.TAB
INDEX.TAB	PDS table listing all files in the DATA directory for the corresponding release and revision.
GEO_MARS.LBL	Detached PDS label to describe GEO_MARS.TAB
GEO_MARS.TAB	PDS table, listing geometric properties of all data products in the DATA directory for the corresponding release and revision.
BROWSE_INDEX.LBL	Detached PDS label to describe BROWSE_INDEX.TAB
BROWSE_INDEX.TAB	PDS table listing all files in the BROWSE directory for the corresponding release and revision, indicating whether a browse product is a full view of the data product (primary) or if it is an individual ionogram associated with the full product (secondary).

The entire content of the INDEX directory will be sent with each release or revision delivered to the PSA.

All index files are patterned according to the standards defined in [AD10], the only difference being the name of the individual columns forming the INDEX_TABLE.

The geometry index file shall include all the geometrical and position information listed in [AD15]. It shall include some of the required PDS keywords as well. The geometry index file fulfils several purposes. It shall allow a user to locate data of interest. Moreover, within the PSA, the geometry index files are read by database software and allow the ingestion of additional parameters into the database.

3.4.3.3 DOCUMENT DIRECTORY

Files in this directory are intended to help the AIS data user understand the requirements influencing the design of the ionospheric sounder portion of the MARSIS radar (the various technical papers), and to utilize the MARSIS AIS data (the two versions of the AIS-specific EAICD).

DOCINFO.TXT	Text description of the directory contents
DOCUMENT.LBL	PDS label for MARSIS AIS documents
MARSIS_EAICD_AIS_L2.TXT	MARSIS AIS-specific EAICD in ASCII text
MARSIS1-0.PDF	Technical Paper: Electron Plasma Frequency in the Martian Ionosphere
MARSIS2-0.PDF	Technical Paper: The Effect of the Ionosphere on Low-Frequency Subsurface Radio Soundings of Mars
MARSIS3-0.PDF	Technical Paper: Ionospheric Electron Densities and Temperature Measurements with the Mars Express MARSIS Instrument
AIS-FREQ-TABLE.TXT	Gives a listing of the 16 tables of frequencies that may be loaded into the MARSIS instrument Parameter Table, and that define the frequency steps used by the instrument while in Active Ionospheric Sounding Mode.
DENS_PROFILE_EX.PDF	A technical description (Morgan, 2008) covering how to derive an electron density profile from the MARSIS AIS data.
DURU_MSTHESIS.PDF	Master's thesis (Duru, 2006) that describes the analysis of oblique ionospheric echos, and the subsequent interpretation in terms of density structures in the Martian ionosphere.

```
MARSIS_EAICD_AIS_L2.DOC MARSIS AIS-specific EAICD in MSWord format

MARSIS_EAICD_AIS_L2.PDF MARSIS AIS-specific EAICD
```

3.4.3.4 LABEL DIRECTORY

The AIS volume LABEL directory contains a file, named AIS_FORMAT.FMT, that describes the format of all AIS Level 2 data products. The LABEL directory also contains the file LABINFO.TXT, which is a plain-text file describing the directory contents.

3.4.3.5 CATALOG DIRECTORY

The Catalog Directory contains the following standard PDS files used to provide detailed descriptions of all aspects of the AIS data set:

AISDS.CAT	PDS catalogue object for AIS data set description
CATINFO.TXT	Text description of the directory contents
INSTRUMENT_HOST.CAT	PDS catalogue object for the spacecraft
MARSISINST.CAT	PDS catalogue object for the instrument
MISSION.CAT	PDS catalogue object for the mission
PERSON.CAT	PDS catalogue object for key persons involved in MARSIS
REFERENCE.CAT	PDS catalogue object for references appearing in the documentation
RELEASE.CAT	PDS catalogue object for current release and revision status of the data set
SOFTWARE.CAT	PDS catalogue object for the software distributed with the data set

3.4.3.6 SOFTWARE DIRECTORY

This directory contains files related to example software applicable to the data on this volume. All code and files are provided "as is" without any warranty but with the hope that they will be useful in understanding the data provided on this volume.

AIS_TESTIN.DAT	Test input data for validating the program
AIS_TESTIN.LBL	Label for test input data
AIS_TESTOUT.TXT	Test output data for validating the program
AIS_TESTOUT.LBL	Label for test output data
READAIS.C	Example source code to demonstrate reading MARSIS AIS data sets
READAIS.LBL	Label for example source code
SOFTINFO.TXT	Description of and instructions for software in this directory

As discussed in earlier sections of this document, he Java-based display tool in in development and will not be available in the initial releases of the AIS data. When the development of the tool and supporting documentation is completed, it will be included as part of an AIS volume release. At that time the appropriate files included in the SOFTWARE directory will be updated to include and describe the Java-based AIS display software.

3.4.3.7 BROWSE DIRECTORY

The BROWSE directory contains Portable Network Graphics (PNG) files survey plots of the data which constitute the primary archive products of this volume. Secondary products are the ionograms for each sounding event during the orbit. These plots are organized by orbit. The detailed structure of this directory is given in section 4.4.2.

3.4.3.8 EXTRAS DIRECTORY

This directory contains additional documentation, specifically an HTML interface to the AIS volume. The HTML files provide links to all browse products via thumbnail versions of individual browse products. The detailed structure of this directory is given in section 4.4.3.

3.4.3.9 DATA DIRECTORY

The DATA directory contains AIS binary data products (.DAT), plus associated label (.LBL) files.

4 DETAILED INTERFACE SPECIFICATIONS

4.1 STRUCTURE AND ORGANISATION OVERVIEW

AIS Level 2 data consist of binary data files and browse data files, each file associated with a detached PDS label. The AIS volume is predominantly organized by orbits as opposed to time, due to the fact that observation intervals are orbit-related rather than time; AIS observations are generally performed during the pericenter passes.

The organization of the AIS L2 data volume is as follows:

```
[MEX-M-MARSIS-3-RDR-AIS-V1.0] (root directory)
    |
    |-AAREADME.TXT     Plain text describing volume contents,
```

```
|                   organization, and its use (this file).
|
|-ERRATA.TXT        Describes known deficiencies or caveats in the
|                   data on this volume.
|
|-VOLDESC.CAT       High level description of volume contents.
|
|-[BROWSE]          Contains browse plots depicting the data.
|    |
|    |-[ACTIVE_IONOSPHERIC_SOUNDER]
|                 |

|                 |-[RDRxxxX]           Plots of the Active Ionospheric
|                       |               Sounder Spectrograms for each
|                       |               orbit.
|                       |

|                       |-[RDRxxxx]     Plots of each Ionogram in the
|                                       orbit xxxx.
|
|
|-[CATALOG]         Information about the Mars Express mission, spacecraft,
|                   and Active Ionospheric Sounder (AIS) Instrument; lists
|                   the cognizant personnel and references revelant
|                   documentation.


|
|-[DATA]          Binary archived data from the Active Ionospheric
|                 Sounder instrument.
|    |
|    |-[ACTIVE_IONOSPHERIC_SOUNDER]
|                 |

|                 |-[RDRxxxX]           Data of the Active Ionospheric
|                                       Sounder for each orbit.
|
|-[DOCUMENT]        Experiment to Archive Interface Control Document (EAICD),
                    instrument technical documentation, etc.
|
|-[SOFTWARE]        Software tools and support documentation for displaying the
                    Active Ionospheric data

|-[EXTRAS]          Bonus content not necessarily conforming to archiving
|                   standards.  Included are HTML files with thumbnails
|                   to navigate the browse products.
|
|-[INDEX]           Volume and cumulative indices of archive products.
|
|-[LABEL]           Format descriptions of the archived data
```

4.2 DATA SETS, DEFINITION AND CONTENT

The AIS instrument has only a single mode of operation. In general, data is organized into ten orbit directories which follow the form RDRxxxx, where xxxx is the four digit orbit number. This applies to the DATA, BROWSE, and EXTRAS directory.

4.2.1 DATA DIRECTORY

The data from the AIS instrument is calibrated and collected into files by orbit. The directory structure is given below.

```
[DATA]
     |
     |-[ACTIVE_IONOSPHERIC_SOUNDER]
          |
          |-[RDRxxxX]
               |
               |-FRM_AIS_RDR_xxxx.DAT
```

The file naming scheme for the data products is FRM_AIS_RDR_xxxx.DAT, where xxxx represents a four digit orbit number (see section 3.1.4 for details). Product design information is given in section 4.3.

4.2.2 BROWSE DIRECTORY

The BROWSE directory contains Portable Network Graphics (PNG) files of survey plots of the data which constitute the primary archive products of this volume. Secondary products are the ionograms for each sounding event during the orbit. These plots are organized by orbits. The general subdirectory structure is as follows:

```
[BROWSE]
   |
   |
   |- [ACTIVE_IONOSPHERIC_SOUNDER]
         |              Active Ionospheric Sounder browse products.
         |
         |- [RDRnnnX]   Contains all data for ten orbits beginning with
               |        a 4-digit orbit nnn0 and ending with a 4-digit
               |        nnn9.  For example, RDR200X contains data for
               |        orbits 2000 to 2009, inclusive.
               |
               |- FRM_AIS_RDR_nnnn.PNG
               |        Active Ionospheric Sounder spectrogram (overview plot)
               |        plot for the entire orbit, where nnnn is a 4-digit
               |        orbit number.
               |
               |- FRM_AIS_RDR_nnnn.LBL
               |        PDS label file for the associated orbit plot.
               |
               |- [RDRnnnn]
                     |      Contains all of the individual ionograms for the
                     |      specified 4-digit orbit (nnnn).
                     |
                     |- FRM_AIS_RDR_nnnn_ccc.PNG
                     |       Active Ionospheric Sounder ionogram for the
                     |       4-digit orbit nnnn in time order, where ccc
                     |       is a counter beginning from the earliest in
```

```
                              |       time.
                              |
                              |- FRM_AIS_RDR_nnnn_ccc.LBL
                              |       The PDS label file associated with the
                              |       PNG browse product.
```

4.2.3 EXTRAS DIRECTORY

This directory contains files associated with extra functionality beyond PDS archiving requirements which we hope will be useful but are not subject to PDS standards. For MARSIS AIS we provide an HTML page which can be used to easily browse the multiple BROWSE products available in the dataset

```
[EXTRAS]
     |
     |-[BROWSEALL]
          |
          |-INDEX.HTM          Top-level HTML link
          |
          |-[ACTIVE_IONOSPHERIC_SOUNDER]
               |
               |-BROWSE.HTM    Links to the thumbnailed plots of the Active
               |               Ionospheric Sounder data.
               |
               |-[RDRxxxX]     Thumbnails for the ionograms grouped into
                    |          ten orbit directories.
                    |
                    |-BROWSE.HTM     HTML file containing the thumbnailed
                                     ionograms for the ten orbits.
```

4.3 AIS DATA PRODUCTS

There are three types of data products included in the MARSIS AIS archive volume:

1) Fully calibrated active ionospheric sounding data stored in binary format.

2) Browse products in the form of overview frequency-time spectrograms. Each overview spectrogram covers a complete pericenter pass.

3) Browse products in the form of individual ionograms. An ionogram is a delay-time vs. frequency plot covering the 160 trasmit/receive intervals.

Geometric information needed to locate observations in space and time is also provided in the GEO_MARS.TAB file located in the INDEX directory. Geometric information is provided for each ionogram.

4.3.1 AIS_RDR DATA PRODUCT DESIGN

AIS_RDR Data Products will be made by a data file containing containing a binary PDS TABLE object along with the associated detached label file, which describing its structure. The data file will contain the instrument data proper, organised into individual frames. A single calibrated AIS frame is a sequence of 160 vectors, each 80 elements long, representing the power received by the instrument in time after transmission of 160 short pulses, each having a different frequency. Each frame is preceded by auxiliary information containing instrument settings and the list of the 160 transmitted frequencies. Each frame will correspond to a record in the data file, which in PDS/PSA terms is referred to as a row in the TABLE object.

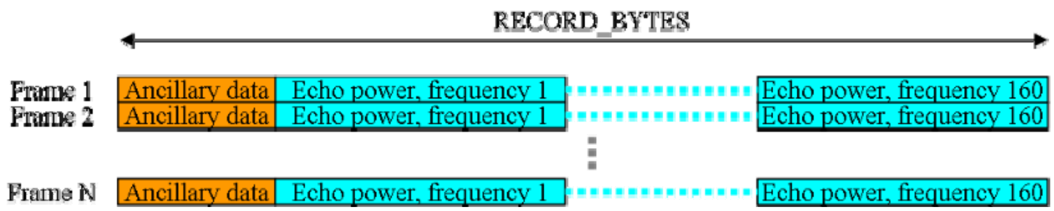
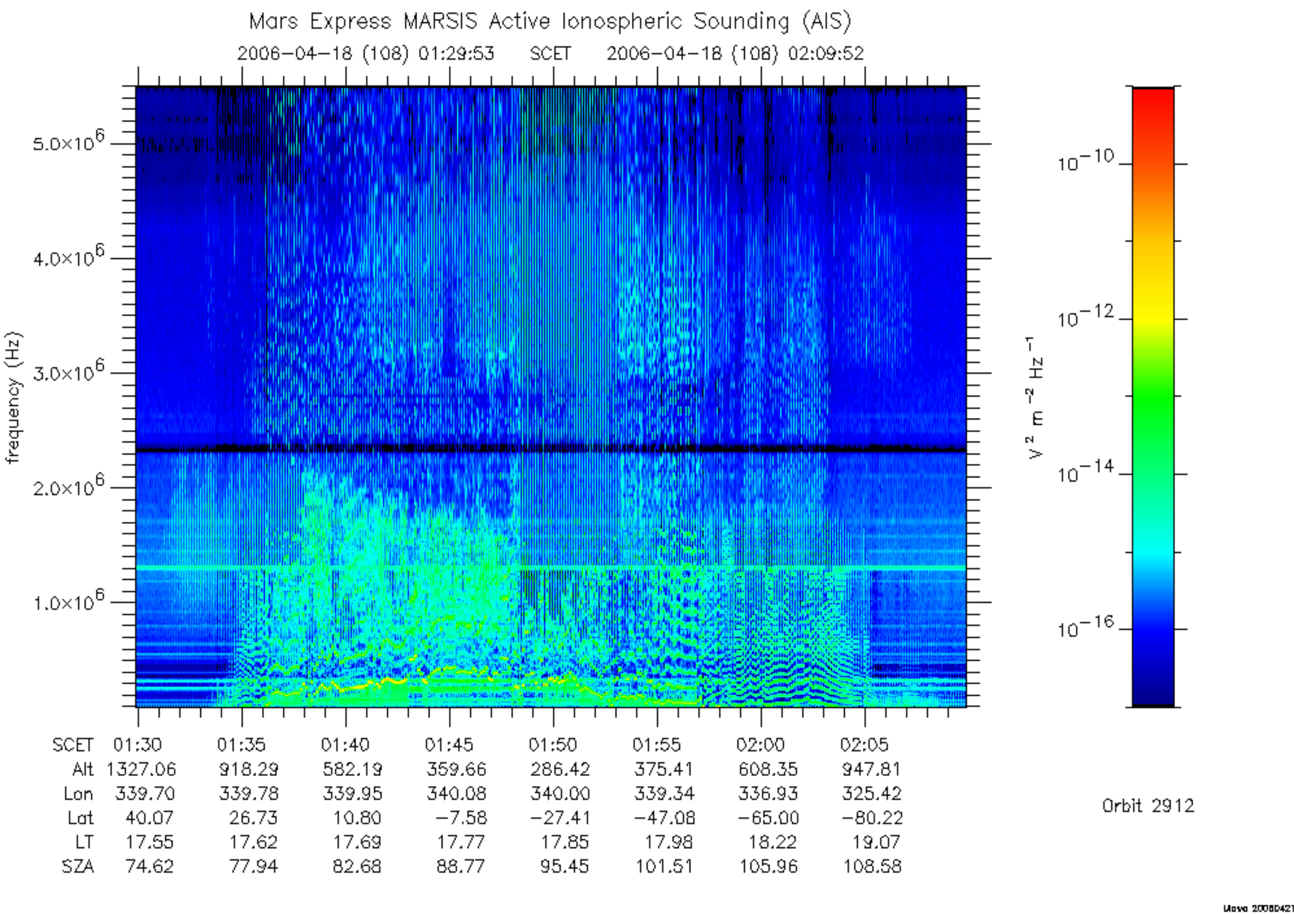


Figure 4.7.1 – 2 Structure of an AIS_RDR Data Product.

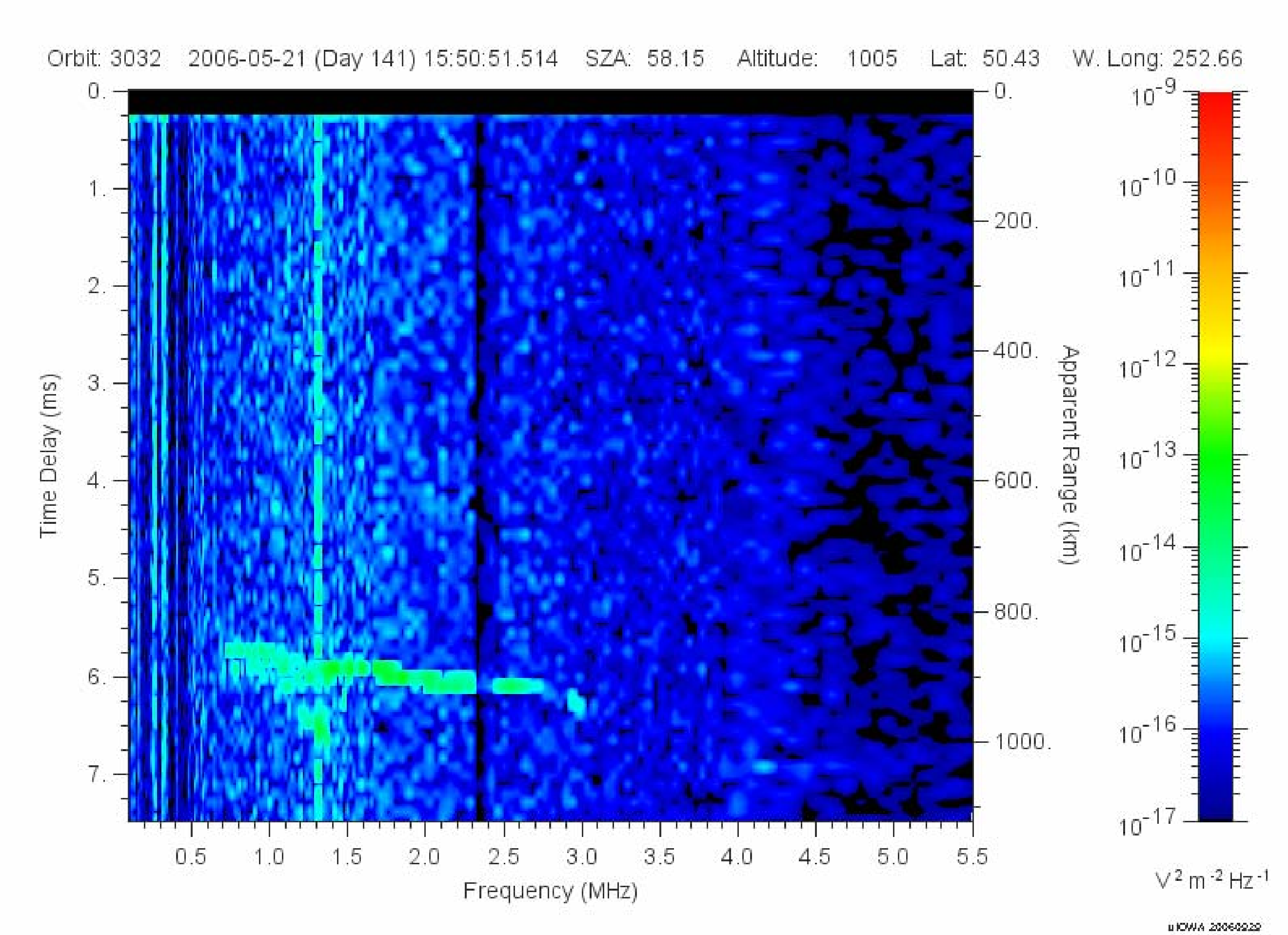
4.3.2 AIS_RDR BROWSE PRODUCT DESIGN (OVERVIEW SPECTROGRAM)

The example overview spectrogram below represents a full pericenter pass, and includes geometry data for that pass. The bright feature at low frequencies is the local (near spacecraft) plasma frequency emission stimulated by the transmit pulse. Signatures at higher frequencies represent both ionosperic and planetary surface echoes.



4.3.3 AIS_RDR BROWSE PRODUCT DESIGN (IONOGRAM)

The example ionogram below represents a single frame collected in Active Ionosphere Sounding mode. The plot represents power received at different frequencies as a function of time delay from the transmission of the pulse at a given frequency. Geometry data is provided for each ionogram. The bright feature is the ionspheric echo signature.



4.4 PDS AIS DATA KEYWORD LIST

The following required list of PDS/PSA keyword-value pairs applies to all MARSIS AIS data. A brief description of each keyword is provided, followed by the value type (i.e. String, Integer), and the actual keyword value used (PDS3, FIXED_LENGTH).

```
PDS_VERSION_ID - This data element represents the version number of the PDS
standards documents that is valid when a data product label is created.
  String
  PDS3

RECORD_TYPE - This element indicates the record format of a file.
  String
  FIXED_LENGTH

RECORD_BYTES - This element indicates the number of bytes in a physical file
record, including record terminators and separators.
  Integer
  400

FILE_RECORDS - This element indicates the number of physical file records,
including both label records and data records.
  Integer
  Equal to the total file length divided by RECORD_BYTES

DATA_SET_ID - This element is a unique alphanumeric identifier for a data set or a
data product. In most cases it is an abbreviation of the DATA_SET_NAME.
STRING
  MEX-M-MARSIS-3-RDR-AIS-V1.0 (nominal mission, through 31 December 2005)
  MEX-M-MARSIS-3-RDR-AIS-EXT1-V1.0 (mission extension 1)
  MEX-M-MARSIS-3-RDR-AIS-EXT2-V1.0 (mission extension 2)

DATA_SET_NAME - This element provides the full name given to a data set. It
typically identifies the instrument that acquired the data, the target of that
instrument, and the processing level of the data.
  String
  MARS EXPRESS MARS MARSIS RDR ACTIVE IONOSPHERE SOUNDING V1.0
  MARS EXPRESS MARSIS RDR ACTIVE IONOSPHERE SOUNDING EXT1 V1.0
  MARS EXPRESS MARSIS RDR ACTIVE IONOSPHERE SOUNDING EXT2 V1.0


PRODUCT_ID - This data element represents a permanent, unique identifier assigned
to a data product by its producer.
  String
  For the AIS data set, PRODUCT_ID is the file name including the extension.

PRODUCT_TYPE - This data element identifies the type or category of a data product
within a data set.
  String
  RDR

RELEASE_ID - This element defines the unique identifier associated with a specific
release of a data set. All initial releases should use a RELEASE_ID value of
'0001'. Subsequent releases should use a value that represents the next increment
```

over the previous RELEASE_ID (e.g., the second release should use a RELEASE_ID of '0002'). Releases are done when an existing data set or portion of a data set becomes available for distribution.
String
From 0001 to 9999

REVISION_ID - This element is a unique identifier associated with a specific revision of a data set release. A data set revision contains the initial data of a data set release or it might comprise supplementary files, that shall be appended to the data set release, or updated files, that shall replace existing files in the data set release, or files existing in the release that shall be deleted from the data set release.
String
From 0000 to 9999

PRODUCT_CREATION_TIME - This element defines the local system format time when a product was created.
Time
Formation rule is YYYY-MM-DDThh:mm:ss

START_TIME - This element provides the date and time of the beginning of an observation in UTC system format.
Time
Formation rule is YYYY-DOYThh:mm:ss.fff

STOP_TIME - This element provides the date and time of the end of an observation in UTC system format.
Time
Formation rule is YYYY-DOYThh:mm:ss.fff

SPACECRAFT_CLOCK_START_COUNT - This element provides the value of the spacecraft clock at the beginning of an observation.
String
Formation rule is p/cccccccccc.fffff where p is the partition number, c stands for SCET_COARSE, and f for SCET_FINE

SPACECRAFT_CLOCK_STOP_COUNT - This element provides the value of the spacecraft clock at the end of an observation.
String
Formation rule is p/cccccccccc.fffff where p is the partition number c stands for SCET_COARSE, and f for SCET_FINE

ORBIT_NUMBER - This element identifies the number of the orbital revolution of the spacecraft around a target body.
Integer
Any value used by the Mars Express project

MISSION_PHASE_NAME
This element provides the commonly-used identifier of a mission phase.
String
Values (ME Phase 1, for example) are determined by the project, and change according to mission phase.

MISSION_NAME - This element identifies a major planetary mission or project. A given planetary mission may be associated with one or more spacecraft.
String
MARS EXPRESS

TARGET_NAME - This element identifies a target.
  String
  MARS

TARGET_TYPE - This element identifies the type of a named target.
  String
  PLANET

INSTRUMENT_HOST_NAME - This element provides the full name of the host on which an instrument is based.
  String
  MARS EXPRESS

INSTRUMENT_HOST_ID - This element provides a unique identifier for the host where an instrument is located.
  String
  MEX

INSTRUMENT_NAME - This element provides the full name of an instrument.
  String
  MARS ADVANCED RADAR FOR SUBSURFACE AND IONOSPHERE SOUNDING

INSTRUMENT_ID - This element provides an abbreviated name or acronym which identifies an instrument.
  String
  MARSIS

INSTRUMENT_TYPE - This element identifies the type of an instrument.
  String
  RADAR

INSTRUMENT_MODE_ID - This element provides an instrument-dependent designation of operating mode. This may be simply a number, letter or code, or a word such as 'normal', 'full resolution', 'near encounter', or 'fixed grating'.
  String
  AIS

INSTRUMENT_MODE_DESC - This element provides an instrument-dependent designation of the INSTRUMENT_MODE_ID in an expanded name format.
  String
  ACTIVE IONOSPHERE SOUNDING

PRODUCER_FULL_NAME - This element provides the full name of the individual mainly responsible for the production of a data set.
  String
  RICHARD L. HUFF

PRODUCER_INSTITUTION_NAME - This element identifies a university, research centre, NASA centre or other institution associated with the production of a data set

  String
  UNIVERSITY OF IOWA

DATA_QUALITY_ID - This element provides a numeric key which identifies the quality of data available for a particular time period.
  String

```
  -1 to 0
```

```
DATA_QUALITY_DESCRIPTION - This element describes the data quality which is
associated with a particular DATA_QUALITY_ID value. The various values of
DATA_QUALITY_ID and DATA_QUALITY_DESC are instrument dependent.
  String
The DATA_QUALITY_ID is described below.
  -1 = data is of little or no science value
   0 = data has no known deficiencies
```

4.5 EXAMPLE PDS AIS DATA PRODUCT LABEL

```
PDS_VERSION_ID                = PDS3
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 400
FILE_RECORDS                  = 12480

LABEL_REVISION_NOTE           = "
  2005-10-01, Robert A. Johnson (U. IOWA), Initial Revision
  2006-08-31, Robert A. Johnson (U. IOWA), Addition of Elements"

DATA_SET_ID                   = "MEX-M-MARSIS-3-RDR-AIS-V1.0"
DATA_SET_NAME                 = "MARS EXPRESS MARS MARSIS RDR
                                 ACTIVE IONOSPHERE SOUNDING V1.0"
PRODUCT_ID                    = "FRM_AIS_RDR_1900.DAT"
PRODUCT_TYPE                  = RDR
RELEASE_ID                    = 0002
REVISION_ID                   = 0000
PRODUCT_CREATION_TIME         = 2005-08-15T17:44:18

START_TIME                    = 2005-189T18:09:07.299
STOP_TIME                     = 2005-189T18:44:53.882
SPACECRAFT_CLOCK_START_COUNT = "1/0068926142.05675"
SPACECRAFT_CLOCK_STOP_COUNT  = "1/0068928288.43886"
ORBIT_NUMBER                  = 1900
MISSION_PHASE_NAME            = "MR Phase 6"
MISSION_NAME                  = "MARS EXPRESS"
TARGET_NAME                   = MARS
TARGET_TYPE                   = PLANET


INSTRUMENT_HOST_NAME          = "MARS EXPRESS"
INSTRUMENT_HOST_ID            = MEX
INSTRUMENT_NAME               = "MARS ADVANCED RADAR FOR SUBSURFACE AND
                                 IONOSPHERE SOUNDING"
INSTRUMENT_ID                 = MARSIS
INSTRUMENT_TYPE               = RADAR
INSTRUMENT_MODE_ID            = AIS
INSTRUMENT_MODE_DESC          = "ACTIVE IONOSPHERE SOUNDING"

PRODUCER_FULL_NAME            = "RICHARD L. HUFF"
PRODUCER_INSTITUTION_NAME     = "UNIVERSITY OF IOWA"
```

```
DATA_QUALITY_ID              = 0
DATA_QUALITY_DESC            = "The DATA_QUALITY_ID is described below.
                                   -1 = data is of little or no science value
                                    0 = data has no known deficiencies"

^AIS_TABLE                   = "FRM_AIS_RDR_1900.DAT"

OBJECT             = AIS_TABLE
  NAME             = AIS_TABLE
  INTERCHANGE_FORMAT = BINARY
  ROW_BYTES        = 400
  ROWS             = 12480
  COLUMNS          = 17
  ^STRUCTURE       = "AIS_FORMAT.FMT"
END_OBJECT         = AIS_TABLE

END
```

APPENDIXES

A AIS FORMAT FILE (AIS_FORMAT.FMT) CONTENT

```
OBJECT                    = COLUMN
  NAME                    = SCLK_SECOND
  DATA_TYPE               = MSB_UNSIGNED_INTEGER
  START_BYTE              = 1
  BYTES                   = 4
  DESCRIPTION             = "Spacecraft clock counter of onboard seconds,
                             since the epoch of May 3, 2003 (123)."
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
  NAME                    = SCLK_PARTITION
  DATA_TYPE               = MSB_UNSIGNED_INTEGER
  START_BYTE              = 5
  BYTES                   = 2
  DESCRIPTION             = "Spacecraft clock counter partition of onboard
                             counter roll-over/reset.  Zero or one
                             indicates the counter is in the first
                             partition.  See the NAIF Spice documentation."
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
  NAME                    = SCLK_FINE
  DATA_TYPE               = MSB_UNSIGNED_INTEGER
  START_BYTE              = 7
  BYTES                   = 2
  DESCRIPTION             = "Spacecraft clock counter of onboard fractions
                             of a second with one fraction being 1/65536."
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
  NAME                    = SCET_DAYS
  DATA_TYPE               = MSB_UNSIGNED_INTEGER
  START_BYTE              = 9
  BYTES                   = 4
  DESCRIPTION             = "Spacecraft event time in days since
                             1958-001T00:00:00Z.  This is the historical
                             epoch used since the launch of the first U.S.
                             satellite Explorer I with Dr. James Van Allen's
                             (University of Iowa) cosmic-ray instrument as
                             the principal element of the payload, resulting
                             in the discovery of the Van Allen Radiation
                             Belts."
END_OBJECT                = COLUMN

OBJECT                    = COLUMN
  NAME                    = SCET_MSEC
  DATA_TYPE               = MSB_UNSIGNED_INTEGER
  START_BYTE              = 13
  BYTES                   = 4
```

```
  DESCRIPTION              = "Spacecraft event time in milliseconds of day.
                              SCET_DAYS and SCET_MSEC are provided to
                              accurately time tag the data in UTC without
                              the need for calls to the spice kernel."
END_OBJECT                 = COLUMN
```

Note: 8 bytes are unused, but are included for 32-bit alignment of the floating point numbers.

```
OBJECT                     = COLUMN
  NAME                     = SCET_STRING
  DATA_TYPE                = CHARACTER
  START_BYTE               = 25
  BYTES                    = 24
  DESCRIPTION              = "Spacecraft event time in UTC in human readable
                              ASCII format."
END_OBJECT                 = COLUMN

OBJECT                     = COLUMN
  NAME                     = PROCESS_ID
  DATA_TYPE                = MSB_UNSIGNED_INTEGER
  START_BYTE               = 49
  BYTES                    = 1
  DESCRIPTION              = "The seven bits from the 20,3 telemetry packet
                              header which determine the instrument process id.
                              0x4D (77d) = Subsurface Sounder (SS1 to SS4)
                              0x4E (78d) = Active Ionospheric Sounder (AIS)
                              0x4F (79d) = Calibration (CAL)
                              0x50 (80d) = Receive Only (RCV)"
END_OBJECT                 = COLUMN

OBJECT                     = COLUMN
  NAME                     = INSTRUMENT_MODE
  DATA_TYPE                = MSB_UNSIGNED_INTEGER
  START_BYTE               = 50
  BYTES                    = 1
  DESCRIPTION              = "The bits from the 20,3 telemetry packet header
                              used to determine the instrument data type and
                              mode selection."
  OBJECT                     = BIT_COLUMN
    NAME                     = DATA_TYPE
    BIT_DATA_TYPE            = MSB_UNSIGNED_INTEGER
    START_BIT                = 1
    BITS                     = 4
    DESCRIPTION              = " 0001 = AIS, Calibration, or Receive Only
                                 0000 = SS1-SS5 Individual Echoes
                                 0010 = SS1-SS5 Acquisition
                                 0011 = SS1-SS5 Tracking "
  END_OBJECT                 = BIT_COLUMN
  OBJECT                     = BIT_COLUMN
    NAME                     = MODE_SELECTION
    BIT_DATA_TYPE            = MSB_UNSIGNED_INTEGER
    START_BIT                = 5
    BITS                     = 4
    DESCRIPTION              = " 0101 = Calibration
                                 0110 = Receive Only
                                 0111 = Active Ionospheric Sounder
```

```
                                1000 = Subsurface Sounder 1
                                1001 = Subsurface Sounder 2
                                1010 = Subsurface Sounder 3
                                1011 = Subsurface Sounder 4
                                1100 = Subsurface Sounder 5 "
  END_OBJECT                  = BIT_COLUMN
END_OBJECT                  = COLUMN

OBJECT                      = COLUMN
  NAME                      = TRANSMIT_POWER
  DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BYTE                = 60
  BYTES                     = 1
  DESCRIPTION               = "The transmit power level, expressed as the
                               power supply regulation voltage for the
                               final power amplifier output.
                                 0x00  (0d) = minimum transmit power  2.5V
                                 0x0F (15d) = maximum transmit power 40.0V "
END_OBJECT                  = COLUMN

OBJECT                      = COLUMN
  NAME                      = FREQUENCY_TABLE_NUMBER
  DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BYTE                = 61
  BYTES                     = 1
  DESCRIPTION               = "The Active Ionospheric Sounder may select
                               one of sixteen frequency tables to use during
                               transmit.  Each table has 160 frequencies
                               that are transmitted during an AIS capture.
                               Table 0 is the default table."
END_OBJECT                  = COLUMN

OBJECT                      = COLUMN
  NAME                      = FREQUENCY_NUMBER
  DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BYTE                = 62
  BYTES                     = 1
  DESCRIPTION               = "The frequency number from the table, ranging
                               from 0 to 159."
END_OBJECT                  = COLUMN

OBJECT                      = COLUMN
  NAME                      = BAND_NUMBER
  DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BYTE                = 63
  BYTES                     = 1
  DESCRIPTION               = "The band that was selected to receive the echo.
                                 0 = band 0      3 = band 3
                                 1 = band 1      4 = band 4
                                 2 = band 2"
END_OBJECT                  = COLUMN

OBJECT                      = COLUMN
  NAME                      = RECEIVER_ATTENUATION
  DATA_TYPE                 = MSB_UNSIGNED_INTEGER
  START_BYTE                = 64
  BYTES                     = 1
```

```
  DESCRIPTION              = "The receiver attenuation for band selected
                              measured in dB."
END_OBJECT                 = COLUMN

OBJECT                     = COLUMN
  NAME                     = FREQUENCY
  DATA_TYPE                = IEEE_REAL
  START_BYTE               = 77
  BYTES                    = 4
  UNIT                     = HZ
  DESCRIPTION              = "The frequency of the transmit pulse"
END_OBJECT                 = COLUMN

OBJECT                     = COLUMN
  NAME                     = SPECTRAL_DENSITY
  DATA_TYPE                = IEEE_REAL
  START_BYTE               = 81
  BYTES                    = 320
  ITEMS                    = 80
  ITEM_BYTES               = 4
  UNIT                     = "VOLT**2/M**2/HZ"
  DESCRIPTION              = "A series of calibrated spectral densities
                              from a single transmit pulse,"
END_OBJECT                 = COLUMN
```

B AVAILABLE AIS SOFTWARE

There are four basic ways a data set user may use the AIS Level 2data set.

1 - By using standard tools provided in Unix/Linux/MacOsX operating systems (example provided below assumes MSB-first byte-order). **Note: This script cannot be guaranteed to execute properly on all platforms**.

```
#!/bin/sh
# simple script file to convert binary AIS data to ASCII text
od -f AIS_TESTIN.DAT | gawk '
{
header++
if(header < 5)
  tmp=0        # do nothing statement
else if(header == 5)
  print $5     # print column 5, the frequency
else if(header < 26 )
  print $2 " " $3 " " $4 " " $5  # density measurements seperated by spaces
else
  header=1     # start over again
}'

# =-=-=-=-=-= end of script file -=-=-=-=-=-=-=-=-=-=-=-=-=

The output should look something like

9.9977109e+04
3.4610298e-14 3.3071479e-23 1.0836890e-15 6.7730581e-16
3.3071479e-23 2.0319160e-16 2.0319160e-15 1.5987795e-12
1.8287253e-15 1.3546115e-16 3.3071479e-23 3.3071479e-23
1.3546115e-16 1.3546115e-16 1.3546115e-16 1.0159581e-14
```

2 - By compiling the included C source software provided in the archive, which is intended to be compatible with Windows, Unix, Linux, and MaxOsX

3 – By writing custom software based on the format information included in the archive documentation

4 - The user may use the Java-based tool provided in the SOFTWARE directory. Please be aware that this tool and the supporting documentation are under development and may not be available in the first deliveries.

The program NasaView is not compatible with AIS L2 data due to the AIS measured values being too small (<10exp-5). NasaView interprets these values as zeros.

C AIS SYSTEM GAIN CALIBRATION TABLE

The following table of 160 calibration value pairs (frequency, system gain in dB) is used to generate calibrated AIS data values in units of electric field spectral density as discussed in section 2.6.1.

109.377KHz	75.12	120.485KHz	75.91	131.167KHz	78.13	142.275KHz	78.23
152.956KHz	78.53	175.174KHz	78.46	185.855KHz	77.98	196.963KHz	77.58
207.645KHz	77.15	218.753KHz	76.81	229.862KHz	76.40	240.543KHz	75.95
251.652KHz	75.51	273.442KHz	74.46	284.550KHz	73.95	295.232KHz	73.21
306.340KHz	72.23	317.021KHz	70.85	328.130KHz	68.48	339.239KHz	65.32
349.920KHz	72.29	361.028KHz	77.65	371.710KHz	77.43	382.818KHz	76.37
393.927KHz	75.57	404.608KHz	74.87	415.717KHz	74.40	426.398KHz	74.02
437.507KHz	73.59	448.615KHz	73.24	459.297KHz	72.95	470.405KHz	72.62
481.086KHz	72.41	492.195KHz	72.21	503.304KHz	71.91	513.985KHz	71.63
525.093KHz	71.38	535.775KHz	71.20	546.883KHz	70.99	557.992KHz	70.81
568.673KHz	70.69	579.782KHz	70.48	601.572KHz	70.16	623.362KHz	69.78
645.151KHz	69.38	667.369KHz	69.05	689.158KHz	68.82	710.948KHz	68.46
732.738KHz	68.16	754.528KHz	67.90	776.318KHz	67.62	808.362KHz	67.26
820.325KHz	67.08	842.115KHz	66.93	863.905KHz	66.60	885.695KHz	66.42
907.912KHz	66.19	929.702KHz	65.89	951.492KHz	65.82	973.281KHz	65.48
995.071KHz	65.28	1017.288KHz	64.99	1039.078KHz	64.83	1082.658KHz	64.50
1104.448KHz	64.22	1126.665KHz	63.96	1148.455KHz	63.70	1170.245KHz	63.43
1202.289KHz	63.01	1213.825KHz	62.87	1236.042KHz	62.62	1257.832KHz	62.52
1279.622KHz	62.28	1323.201KHz	53.67	1345.418KHz	53.94	1367.208KHz	54.15
1388.998KHz	54.41	1410.788KHz	54.53	1432.578KHz	54.67	1454.795KHz	54.80
1476.585KHz	54.88	1498.375KHz	54.90	1520.165KHz	54.99	1541.955KHz	55.03
1564.172KHz	55.09	1585.962KHz	55.11	1607.752KHz	55.22	1629.541KHz	55.25
1651.331KHz	55.30	1673.548KHz	55.29	1717.128KHz	55.34	1760.708KHz	55.33
1804.715KHz	55.37	1848.295KHz	55.52	1892.302KHz	55.69	1935.882KHz	55.85
1979.461KHz	56.02	2023.468KHz	56.11	2067.048KHz	56.15	2110.628KHz	56.14
2154.635KHz	56.18	2198.215KHz	56.24	2242.222KHz	56.31	2285.801KHz	56.30
2329.381KHz	56.16	2373.388KHz	56.01	2416.968KHz	55.86	2460.975KHz	55.70
2504.555KHz	55.71	2548.135KHz	56.22	2592.142KHz	56.54	2635.721KHz	56.74
2679.728KHz	56.90	2723.308KHz	57.11	2766.888KHz	57.30	2810.895KHz	57.61
2854.475KHz	57.79	2898.482KHz	57.92	2942.061KHz	57.99	2985.641KHz	58.07
3029.648KHz	58.22	3073.228KHz	58.41	3117.235KHz	58.61	3160.815KHz	58.72
3204.395KHz	58.80	3248.402KHz	58.75	3291.981KHz	58.83	3335.988KHz	58.95
3379.568KHz	59.11	3423.148KHz	59.16	3467.155KHz	59.11	3510.735KHz	58.94
3554.314KHz	59.78	3598.322KHz	60.30	3641.901KHz	60.66	3685.908KHz	61.04
3729.488KHz	61.41	3773.068KHz	61.80	3817.075KHz	62.29	3860.655KHz	62.60
3904.662KHz	62.89	3991.821KHz	63.48	4079.408KHz	64.37	4166.995KHz	65.15
4254.582KHz	65.57	4342.168KHz	66.19	4429.328KHz	66.51	4516.915KHz	66.04
4604.501KHz	67.33	4692.088KHz	67.23	4779.675KHz	66.79	4866.835KHz	66.02
4954.421KHz	64.89	5042.008KHz	63.77	5129.595KHz	62.80	5216.754KHz	61.49
5304.341KHz	60.11	5391.928KHz	58.94	5479.515KHz	57.32	5501.305KHz	56.70