

# User Guide to the RPC-MIP Science Datasets in the ESA's Planetary Science Archive (PSA)

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## Document Status Sheet

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## List of Acronyms

DFT	Discrete Fourier Transform
ESA	European Space Agency
FFT	Fast Fourier Transform
HK	House Keeping
LAP	LAnghmuir Probe
LDL	Long Debye Length
LPC2E	Laboratoire de Physique et Chimie de l'Environnement et de l'Espace
MIP	Mutual Impedance Probe
OCM	Orbit Correction Manoeuvre
PIU	Plasma Interface Unit
PSA	Planetary Science Archive
RD	Reference Document
RPC	Rosetta Plasma Consortium
SDL	Short Debye Length
TC	Telecommand
UTC	Coordinated Universal Time
WOL	Wheel Off Loading

## Reference Documents

RD1	Rosetta Plasma Consortium users's manual, RO-RPC-UM, issue 2.18, 2011
RD2	Rosetta project – MIP experiment – Onboard data handling, RPC/MIP/RP/13/980317/LPCE, issue 3.4, 2000
RD3	ROSETTA archive conventions, RO-EST-TN-3372, issue 10.1, 2017
RD4	RPCMIP/RPCLAP Cross-Calibration Report, RPC_MIPLAP_CROSSCAL_REPORT, 2018



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## 1. Introduction

The RPC-MIP (Mutual Impedance Probe) is one of the five instruments of the Rosetta Plasma Consortium (RPC) on board the ESA Rosetta mission. RPC-MIP is an active electric sensor that measures the transfer impedance between a transmitter (monopole or dipole) and a receiving dipole. It operates in the [7-3500] kHz frequency range in different frequency bands and different frequency resolutions. In active mode (with the transmitter(s) on), it acquires spectra that can be analysed to determine some of the plasma bulk characteristics, among which the electron plasma density. In passive mode (transmitter(s) off), the receiving dipole is an electric field antenna that measures one component of the electric field, corresponding to plasma waves not generated by RPC-MIP itself.

This document is provided as a user guide for the RPC-MIP datasets available at the ESA's Planetary Science Archive (<https://www.cosmos.esa.int/web/psa/rosetta>) and explains key science datasets. While concepts about the Rosetta Plasma Consortium and RPC-MIP instruments are detailed in RD1 and RD2, the information contained in this document should be sufficient for the user to understand the instrument goals and operational concepts and to access and work with the RPC-MIP data in the PSA archive.

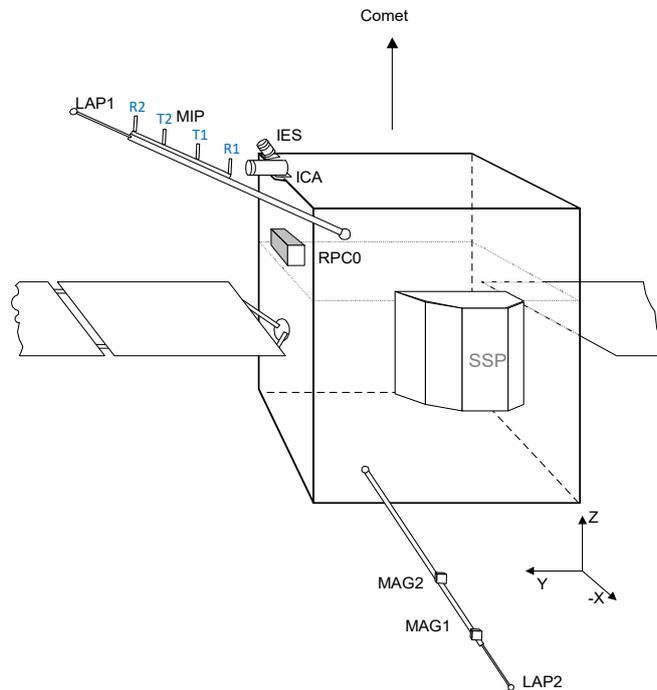
## 2. Instrument Description

The RPC-MIP instrument is composed of two main elements:

- A sensor unit,
- An electronics board.

The sensor is mounted on the upper boom (2m length, deployed towards the comet facing side in the nominal operation attitude i.e. when pointing nadir) of the Rosetta orbiter spacecraft, as illustrated on figure 1. The electrode array is linear and includes one receiving dipole (R1 - R2) and two transmitting monopoles (T1 and T2) supported by a conductive bar, about 1 m in length and 2 cm in diameter. This bar is insulated from the S/C structure, and is kept at a reference potential. The separation between each receiving electrode and the nearest transmitting monopole is 40 cm. The receiving electrodes are located at the ends of the bar, 1m apart, in order to maximize the effective length of the antenna for wave measurements, in the passive mode.

Each electrode is made of a cylinder mounted at the tip of a stud and electrically decoupled from this stud by an insulating sheath. The stud is longer than the tip cylinder in order to reduce the perturbing effect of the supporting bar. The overall dimensions of the electrodes and supports are 20 cm in length and 1.1 cm in diameter.



**Figure 1:** RPC Sensors Layout (deployed).  
 (Extracted from RD1)

In the active mode, RPC-MIP can be operated with different transmitting configurations:

- T1 and T2 can be used independently as a monopole transmitter or conjointly in phase or in phase opposition, as a dipole (or stereo) transmitter. Due to its technical principle, this enables to properly analyze plasmas with a Debye length lower than a few tens of cm in the so-called Short Debye Length mode (SDL)
- To overcome this limit, a so-called Long Debye Length mode (LDL) has been implemented. In this mode, one of the two Langmuir probes of the RPC-LAP instrument (LAP2) is used as a monopole transmitter, enabling plasmas with Debye length up to few meters to be investigated. Note that the transitions from SDL to LDL operational modes were not automatic, but planned by telecommand (typically a couple of weeks in advance).
- In both cases, the reception is performed by the RPC-MIP receivers R1 and R2.

The following notations are used above and hereafter:

- R1 and R2 are the receivers and T1 and T2 are the transmitters of the RPC-MIP antenna (from the hinge to the end of the upper boom, see figure 1)
- LAP2 is the transmitter used in LDL mode (fixed at the end of the lower boom, at about 4m of RPC-MIP electrodes)

The location of the electrodes in the S/C frame are listed in the following table (positions are given in mm).

Transmitters			Receivers	
SDL mode	T1	X (s/c) = -967 Y (s/c) = +1852 Z (s/c) = +3302	R1	X (s/c) = -967 Y (s/c) = +1569 Z (s/c) = +3019
	T2	X (s/c) = -967 Y (s/c) = +1994 Z (s/c) = +3444	R2	X (s/c) = -967 Y (s/c) = +2277 Z (s/c) = +3727
LDL mode	LAP2	X (s/c) = -2482 Y (s/c) = +780 Z (s/c) = -670		

**Table 1:** Position of receiving and transmitting electrodes used by RPC-MIP, in S/C frame.

The orientation of the RPC-MIP sensor with respect to the S/C is given in the SPICE FK kernel ROS\_Vxx.TF (with xx the version number) that can be found on the PSA in the Ancillary data associated to the Rosetta mission.

The RPC-MIP instrument measures the electrical coupling of a transmitting antenna and a receiving antenna. No direct contact between the sensor and the plasma is required because the coupling is capacitive only. Therefore, RPC-MIP performance is independent of the chemical composition and photoemissive properties of the probe. It is also immune to contamination by dust and ice deposits.

In its passive mode, this instrument has also the capability of a plasma wave analyzer.

The electronics board is located inside the RPC-0 box. It assumes four functions listed below:

- Acquisition of the analog signal from 7 kHz to 3.5 MHz,
- Data processing using FFT and DFT calculations and some mathematical functions,
- A FPGA controls the frequency synthesis and the data storage,
- A second FPGA manages the transfer protocol (IEEE 1355) with the RPC-PIU who acts as instrument control, spacecraft interface, and power management unit.

### 3. Scientific objectives

Mutual impedance probes, such as RPC-MIP, measure the transmission properties of the electric field in a plasma through the mutual impedance of two electric antennas. Under certain conditions of the sounded cometary plasma, a careful on-ground analysis of the acquired spectra can lead to some of the plasma bulk characteristics of the plasma, such as the electron density and potentially the electron temperature.

RPC-MIP has been designed to access the plasma density of the ionized outflowing cometary atmosphere, and estimate the electron temperature under certain plasma conditions. The investigation of these plasma parameters, combined with other plasma and electro-magnetic parameters measured by the other RPC instruments, enables to better constrain extra bulk plasma parameters (such as the electron temperature and the ion bulk velocity, under certain hypothesis) and contributes to the understanding of the ionization of the cometary atmosphere, as well as the thermalization, the structure and the dynamics of the expanding cometary ionosphere (also called by some authors “induced magnetosphere”) and its interaction with the incoming solar wind.

RPC-MIP’s additional goals include defining the spectral distribution of natural plasma waves, through the measurement of the electric field projected along the direction of the instrument, in the frequency range from 7 kHz to 3.5 MHz, i.e. above the electron cyclotron frequency under cometary plasma conditions encountered around 67P/C.

The scientific rationale underpinning the RPC-MIP archive in the PSA system is as follows:

- Maximize the scientific return from the experiment by making available both the calibrated (L3) and interpreted (L5) RPC-MIP data to the world-wide scientific community,
- Ensure that the unique data set returned by RPC-MIP is preserved in a stable, long-term archive for scientific analysis beyond the end of the Rosetta mission,
- Provide this archive as a part of the valuable contribution by ESA and the Rosetta science community to the exploration of comets.

## 4. Instrument Operations

### 4.1 Instrument operational modes

The RPC-MIP in-flight operations are controlled by a configuration table sent from ground by telecommand (TC) and setting the operational parameters values.

The main operational concepts are described below.

- **Active and passive mode**

In **active mode**, a transmission signal is injected through one electrode (T1, T2 or LAP2) or the dipole (T1 and T2) at a given frequency. Contemporarily, the signal is received on the reception dipole (R1-R2) and is Fourier transformed (DFT) at the frequency of the transmitted signal, with a 7 kHz resolution. A sweep over the selected frequency table allows the computation of the overall spectral response.

Possible transmission configurations are:

- Dipole (stereo) transmission on T1 and T2 in phase (also referred as “phased dipole mode”)
- Dipole (stereo) transmission on T1 and T2 in phase opposition (also referred as “antiphased dipole mode”)
- Monopole transmission on T2 (with T1 off)
- Monopole transmission on T1 (with T2 off)
- Monopole transmission on LAP2 (with T1 and T2 off)

In **passive mode**, when no transmission is applied, the received signal is processed by a FFT over the whole bandwidth (with a maximum frequency resolution of 7 kHz, like in active mode).

- **SDL/LDL**

A relay can be activated by TC to switch between SDL and LDL modes (see section 2). In SDL mode, the scanned table frequency is chosen among several on board pre-loaded tables with various frequency ranges and resolutions (but always with 92 frequency bins) while the frequency table in LDL is fixed, with 24 frequency bins (7 kHz resolution) in the range [7 - 168] kHz.

Details for the available frequency tables for SDL and LDL modes can be found in Appendix A.1 and RD2 but this knowledge is not required for interpreting RPC-MIP data as frequency values are always provided for each individual spectrum contained in the archive.

- **Active modes**

Three active modes have been designed for the RPC-MIP instrument:

- LDL when LAP2 is transmitting in LDL mode
- SURVEY when in SDL mode
- SWEEP when in SDL mode

SWEEP and SURVEY active modes are identical, except for the frequency table used. The SWEEP mode is a standard spectrum acquisition that immediately follows a SURVEY mode which resonance (frequency of the power spectrum maximum) has been automatically detected on-board. This resonance frequency can be used to automatically select the best suited frequency table of the SWEEP mode among the pre-loaded frequency tables available on-board (the frequency table used for the SWEEP mode can also be forced by TC). Note that the triggering SURVEY mode is not transmitted in the TM.

- **Sub-modes**

Several sub-modes have been defined to adapt the amount of generated data to the available telemetry and operating strategies.

Sub-modes are:

- FULL: all the computed values for the power spectrum (92) and a selection of values for the phase<sup>1</sup> spectrum (28) are transmitted for SURVEY and SWEEP modes. All the computed values for the power and phase spectra (24) are transmitted for LDL mode. All the (96) power values are transmitted for PASSIVE mode
- WINDOW: only a portion of the power spectrum is transmitted (a window around the resonance detected on-board) corresponding to 14 values for SURVEY and SWEEP modes and 15 values for LDL mode. In PASSIVE mode, only the first 48 power values are transmitted
- MINMAX (only valid for active modes): the two highest maxima and two lowest minima of the power spectrum, detected on-board, are transmitted in the telemetry (frequency and amplitude)
- POWER (only valid in passive mode): two averaged power values are transmitted: one in the [7 – 448] kHz frequency range (LF part) and one in the [476 – 3584] kHz frequency range (HF part)

More details on sub-modes are provided in Appendix A.2.

Operation concepts and RPC-MIP modes are extensively described in RD2.

## 4.2 Sequencing and time resolution

The RPC-MIP sequencing depends on the selection of a sequence among several possible on-board sequences. This selection is done by TC and takes into account operational constraints and/or scientific considerations (available resources, orbit, science campaign ...).

Each sequence correspond to a different combination of active and passive sub-modes. All or part of the corresponding information is then transmitted in the telemetry and decoded on-ground. This results in a set of data acquired with different sub-modes within one sequence. Sub-modes are decorrelated in the RPC-MIP archive and data from different operational modes and sub-modes are provided as separate data files. Note that depending on the operational strategy, all sub-modes are not always operated at the same time.

All sequences have the same duration of 32 seconds (one instrument cycle) but depending on available telemetry, they do not perform the same number of acquisitions nor provide the same information, thus resulting in a time resolution that depends on the selected sequence. Note that in the case of the SWEEP mode, active measurements are performed without

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<sup>1</sup> Note that the term “phase” is used in this document to indicate two different notions: (i) the spectral phase of the mutual impedance complex spectrum (associated to a spectral amplitude) and (ii) one of the operational mode of the RPC-MIP experiment in SDL mode, with the two transmitters T1 and T2 oscillating in phased dipole mode.

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providing the corresponding measurement in the data files. Note also that idle periods exist within one sequence thus leading to an irregular time resolution.

The time resolution for RPC-MIP data thus depends on the chosen operating sequence and on the considered data sub-mode.

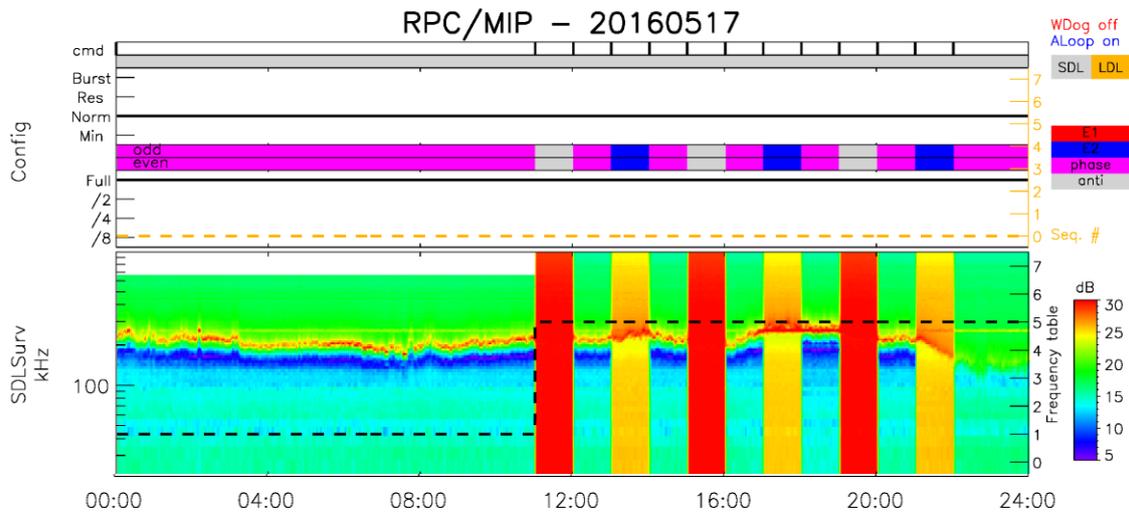
Appendix A.3 gives detailed information on the composition and sequencing of RPC-MIP operational sequences for different telemetry rates. Operational information such as sequence number can be found in a dedicated dataset containing the instrument configuration. Standard users should not care about the detail of sequencing as UTC is provided for each individual measurement or derived product.

## 5. Instrument in-flight calibration

Data are on-board calibrated in physical units (for both active and passive modes). Each time the instrument is switched on, an automatic calibration sequence is run. First, an auto-loop process connects directly the transmitted signal to the analogue reception inside the RPC-MIP board in order to automatically check the transmission levels at each frequency. Second, a FFT is processed on given values to verify that the FFT calculation is correct.

During the mission lifetime, several in-flight calibration campaigns have been performed to study the influence of the transmission configuration (monopole or dipole, various transmission levels). The figure below shows an example of such in-flight calibration campaign, where the transmission configuration was alternated between T2 monopole, phased dipole and antiphased dipole. The effect on the instrument response is clearly seen. These campaigns can be used to better qualify the instrument response with respect to the transmission configuration, which can be of interest for a refined analysis and density estimation.

The list of these in-flight calibration campaigns can be found in Appendix A.6.



**Figure 2:** Example of in-flight calibration for May 17<sup>th</sup>, 2017. From top to bottom: instrument operations parameters (HK) with different transmitter configuration (between phased, antiphased and mono E2) and power spectrogram in SDL active mode. Note that the color scale is unique for all transmission configurations so that it does not allow to see in this graphic the spectral signatures at the plasma frequency in antiphased dipole mode.

## 6. Determination of derived parameters

The main scientific objective of the RPC-MIP instrument is to determine the plasma (electron) density. This can be achieved by identification of the plasma frequency through the analysis of mutual impedance spectra. This derived density is available in the PSA archive.

The electron temperature can be estimated through different methods:

- (i) If the Debye length  $\lesssim d_{\text{transmitter-emitter}} / 10$ , the electron temperature can be inferred from the analysis of the anti-resonances pattern observed above the plasma frequency in the mutual impedance spectra (Trotignon et al, 2007). However, this condition has not been observed in the comet environment of 67P/CG.
- (ii) In presence of two different electron populations (with different temperatures), as sometimes observed at CG67-P, a method based on the analysis of mutual impedance spectra has been developed and described in Gilet et al (2017).
- (iii) Moreover, temperature estimates can also be derived from combined analysis of RPC-MIP derived density and RPC-LAP measurements (I-V curves), as described in Odelstad et al (2018).

Such methods have been implemented for specific science case studies but their automatization is out of the scope of the PSA archive, so that the electron temperature is not provided as a dataset. However, all needed inputs are included in the PSA enabling users to conduct their own analysis.

## 6.1 Electron density from RPC-MIP measurements

The mutual impedance spectral amplitude exhibits a peak (resonance) close to the electron plasma frequency ( $f_{pe}$ ) and may exhibit an interference pattern at frequencies higher than the plasma frequency, depending on the electron temperature, whenever the magnetic field is weak enough to be neglected. Conversely, when the electron cyclotron frequency ( $f_{ce}$ ) becomes of the same order of magnitude as the electron plasma frequency  $f_{pe}$ , other resonances and anti-resonances are usually observed at  $f_{ce}$  harmonics, the upper hybrid frequency, and Bernstein frequencies. Note that these features have only been observed at Earth fly-bys, but have never been observed in the plasma environment of comet 67P/CG, where the electron cyclotron frequency is much smaller than the plasma frequency.

The electron plasma density can be derived from the mutual impedance spectral pattern on a case-by-case basis, using results from plasma environment simulations and from a model of the RPC-MIP response (Trotignon et al., 2007).

Ad-hoc algorithms have been developed to extract the plasma frequency from the RPC-MIP power spectra. These algorithms are based on the recognition of typical features (minimum, cut-off and maximum) characterizing the shape of the measured mutual impedance spectrum. Thresholds in amplitude and/or in frequency are imposed to remove dubious signatures or spectra with low signal-to-noise ratio from the analysis. These thresholds are adapted to the different operational configurations of the instrument and known interferences are taken into account. Note that, for the LDL mode, phase spectra are also analysed for a refined validation. Extracted spectral characteristics are then converted to plasma frequency ( $f_{pe}$ ) on the basis of theoretical studies (including occurrences of double electron populations as described in Gilet et al, 2017). Additional information such as uncertainty of the plasma frequency and quality indexes are also derived from the analysis.

The electron density and associated uncertainty are then derived through:

$$n_e = \frac{f_{pe}^2}{\alpha}$$

$$\Delta n_e = \frac{2}{\alpha} \cdot f_{pe} \cdot \Delta f_{pe}$$

Where  $\alpha$  is a constant given by:  $\alpha = \frac{e^2}{4\pi \epsilon_0 m} = 80.7 \text{ kHz}^2 \cdot \text{cm}^3$

The resulting derived electron density and associated parameters are provided as a RPC-MIP L5 dataset (see section 8.7 for more details about the content). The efficiency of the detection

algorithm depends on the plasma regime and on the signal-to-noise ratio at the time of acquisition, resulting in a non-continuous coverage.

## 6.2 Electron density from cross-calibration between RPC-MIP and RPC-LAP

While absolute measurements of the electron plasma density, through the identification of the plasma frequency in RPC-MIP spectra, are believed to be accurate, scientific analyses are limited by the instrument capabilities in terms of time resolution, frequency resolution and accessible density range. Combining these products with floating potential as well as ion and electron currents and/or electric potentials measured by RPC-LAP enables to validate and increase the time resolution of the RPC-MIP derived density. This cross-calibration effort between instruments among the RPC leads to the delivery of a common L5 density dataset between RPC-MIP and RPC-LAP that complement the RPC-MIP-only L5 density dataset<sup>2</sup>.

Cross-calibrated densities are obtained by fitting different RPC-LAP measurements to RPC-MIP electron densities over fixed-length overlapping sliding time windows.

Inputs are listed below.

- RPC-MIP derived densities obtained in SDL phased and SDL antiphased modes of operation, available as a L5 dataset on the PSA.
- RPC-LAP potential and currents obtained from probes operated in floating mode or current mode, respectively, available as L5 datasets on the PSA.

Possible issues regarding the use of RPC-MIP and RPC-LAP input datasets for such cross-calibration purpose is a priori limited by a careful selection of possible cross-calibration intervals. This is obtained through (i) a prioritization among RPC-MIP measurements that enable to extract the plasma density, (ii) a prioritization among possible RPC-LAP measurements to be cross-calibrated, and (iii) by discarding events where the measurements quality can be limited (such as attitude correction manoeuvres, RPC-LAP probes illumination conditions...).

Results from the cross-calibration procedures are filtered out to discard false detections, for instance time intervals when the assumptions adopted for the cross-calibration process could be doubtful.

A more detailed description of the cross-calibration procedure can be found in RD4.

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<sup>2</sup> planned to be available in the PSA in summer 2019

## 7. Archive format and content

The RPC-MIP archive naming, format and content follow conventions given in RD3. We only recall here the minimum knowledge needed to the user to identify the various data files contained in the archive.

Data processing level number used in RPC-MIP datasets conforms to CODMAC norm:

Level	Description
3	Calibrated Data: <i>“Edited data that are still in units produced by instrument, but that have been corrected so that values are expressed in or are proportional to some physical unit such as radiance. No resampling, so edited data can be reconstructed”</i>
5	Derived Data: <i>“Derived results, as maps, reports, graphics, etc “</i>

A data set will be delivered for each **simple mission phase**. Each data set will contain **only one (CODMAC) data processing level**.

Two data levels are provided in the RPC-MIP archive. All the RPC-MIP datasets are given in physical units.

The **L3 calibrated** (or ‘edited raw’):

- **Science data** (in **active mode**: electric field spectra modulus and phase, resonance values; in **passive mode**: electric field spectra modulus, mean passive power inside a particular frequency bandwidth) for both SDL and LDL modes. A level 3 file contains data from one RPC-MIP sub-mode. The time resolution depends on the data, on the telemetry rate and on the onboard operated RPC-MIP sequence (selected by TC) and ranges from 2.65 s to 32 s.
- **House-keeping data** (sequence counters, mean passive power, resonance values, sensor temperature and configuration table): contains HK data concerning the active and passive sweeps: RPC-MIP power in passive mode, resonance power in active mode, resonance frequency in active mode. The time resolution is 32 s.

The **L5 derived** (or ‘higher-level’):

- **RPC-MIP electron densities** are derived from the analysis of RPC-MIP spectra. Note that it is not always possible to derive accurately the density, resulting in an irregular sampling in time. Values are given in  $\text{cm}^{-3}$  with a time resolution at most equal to the instrument time resolution which depends on operational parameters.

- **RPCMIP/RPCLAP plasma densities** are derived from the cross-calibration of RPC-MIP electron densities and RPC-LAP measurements. This dataset is not provided with a full coverage over the mission but only on selected intervals. The resulting time resolution is driven by the RPC-LAP time resolution which is much better than with RPC-MIP alone, typically from  $\sim 2.5$  seconds at most for RPC-MIP (in BM LDL operational mode) to  $\sim 0.02$  seconds for the cross-calibrated RPCMIP/RPCLAP density.

Note also that, under certain conditions, by combining RPC-MIP data with measurements from different RPC instruments, the electron temperature and the plasma bulk velocity can also be estimated. While this can sometimes be done for science cases, it is not foreseen that these latest parameters will be part of the RPC-MIP archive.

## 7.1 Dataset name and ID

Each RPC-MIP dataset has a unique name and identifier (ID) constructed following conventions in RD3:

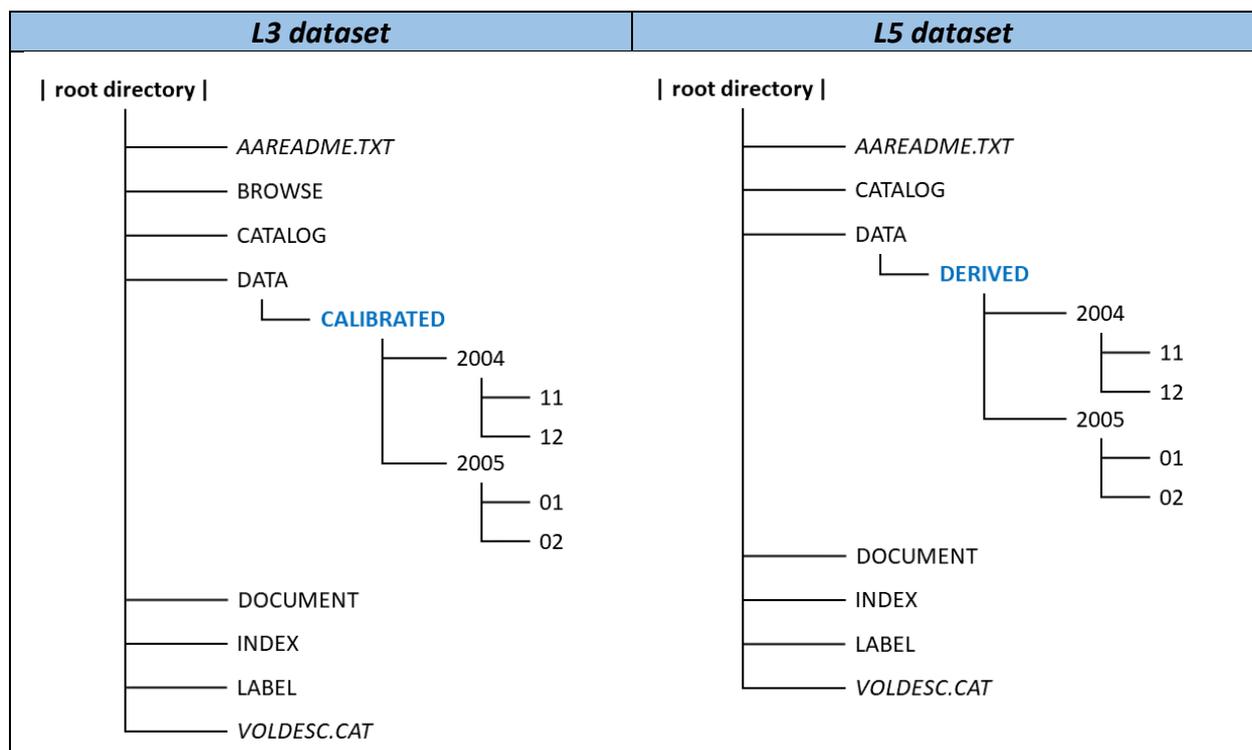
- DATA\_SET\_NAME = **ROSETTA-ORBITER** *<target name>* *<instrument\_id>* *<codmac level>* *<abbreviation>* *<version>*
- DATA\_SET\_ID = **RO-***<target id>*-*<instrument\_id>*-*<codmac level>*-*<abbreviation>*-*<version>*

where:

- *<target name>*, *<target id>*, *<abbreviation>* depend on the mission phase. Values for all mission phases can be found in Appendix A.4,
- *<instrument\_id>* is **RPCMIP** for L3 RPC-MIP datasets and RPC-MIP L5 density dataset and **RPCMIP/RPCLAP** for RPCMIP/RPCLAP cross-calibrated density dataset,
- *<codmac level>* refers to the data processing level and is equal to "3" or "5" for L3 or L5 datasets, respectively,
- *<version>* refers to the dataset version number, e.g. "V1.0".

## 7.2 Content of RPC-MIP datasets

The structure of the RPC-MIP dataset slightly differs between L3 and L5 datasets, details are provided below:



**Table 2:** RPC-MIP datasets structure

The AAREADME.TXT file is an ASCII file providing general information on the dataset and its content.

The files in the CATALOG directory provide top-level information on the mission, spacecraft, instrument and dataset. It contains the following files:

File Name	File Contents
CATINFO.TXT	A description of the contents of the CATALOG directory
DATASET.CAT	Dataset information
INST.CAT	Instrument information Note that for cross-calibrated L5 datasets, both RPC-MIP and RPC-LAP catalogs are provided
INSTHOST.CAT	Instrument host (Spacecraft-Orbiter) information
MISSION.CAT	Mission information
PERSON.CAT	Information about the instrument team
REF.CAT	Full citations for references mentioned in any and all of the catalog files, or in any associated label files.

SOFTWARE.CAT	Information on provided software (no software is delivered for RPC-MIP)
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**Table 3:** RPC-MIP PSA catalogs.

The DATA directory of each dataset is divided with respect to data level (calibrated or derived) and then sub-divided in years, month and day. Details on data files format and content are given in the following sections.

The INDEX directory contains information to help locate products in the dataset. It is of minor interest for a standard user.

The content of the LABEL directory depends on the (CODMAC) data level. It contains ASCII files (.FMT) describing the content and format of the different data files found in the dataset. There is one FMT file per data type.

The content of the DOCUMENT and BROWSE directories is described in section 7.3 and 8.2, respectively.

The VOLDESC.CAT file contains a general description of the contents of the dataset.

### 7.3 Documents

A number of documents describing the instrument and the archives content are available in the DOCUMENT directory, as described below.

<i>Document name</i>	<i>Content</i>	<i>Available in</i>		
		<i>L3</i>	<i>RPC-MIP L5</i>	<i>Cross-calibrated L5</i>
RO_RPCMIP_LOGBOOK_xxx.TXT	A logbook, containing information on the instrument operations or caveats (one single file for the mission lifetime)	✓		
BOARD_PROC_xx.PDF	MIP experiment Onboard Data Handling	✓	✓	
MIP_PIU_INTERF_xx.PDF	MIP/PIU Data Handling Interface	✓	✓	
RPC_UM_xx.PDF	Rosetta plasma consortium users' manual	✓	✓	
RPC-MIP-UG-LPCE.PDF	User Guide to the RPC-MIP datasets in the ESA's PSA (this document)	✓	✓	✓
RPC_USER_GUIDE.PDF	RPC user guide	✓	✓	✓
MIP_EXP_OVERVIEW.PDF (L3) or TROTIGNON2007.PDF (L5)	RPC-MIP experiment description: Trotignon et al (2007)	✓	✓	✓
ERIKSSON2007A.PDF ERIKSSON2008A.PDF	RPC-LAP experiment description: Eriksson et al (2008)			✓
RPC_MIPLAP_CROSSCAL_REPORT.PDF	RPCMIP/RPCLAP cross-calibration report describing the RPCMIP/RPCLAP cross-calibrated science dataset on the PSA			✓

**Table 4:** Available documentation.

In the table above, xx stands for the document version number.

## 8. RPC-MIP data files

### 8.1 RPC-MIP data types

Data are given as ASCII files (.TAB) included in the sub-directories of the DATA directory. Each file is associated to a descriptor file (.LBL) which contains a reference to an object describing the content of each column. These objects are stored as FMT files and can be found in the LABEL directory.

For L3 datasets, each RPC-MIP file contains data from one measurement session (period between instrument ON and instrument OFF). One session can be determined using the time difference between successive (chronologically) data (spectra, configuration tables or HK parameters). If this difference is greater than 100 minutes, a new session begins and a new file is created. Different data types exist. Each data type is related to an operational mode and is associated to a FMT file (contained in the LABEL directory).

For L5 datasets, derived parameters are provided as daily files.

The filenaming convention is defined in RD3. The following table gives the filename and the FMT file associated to each data.

Level	Physical quantity	Operating mode	Filename	FMT file	
L3	E-field Power spectrum	Active	RPCMIPS3WSXyyymmddhhmn_XXXXX.TAB	MIP_SPECTRUM_S_SS_PO_X.FMT	
			<i>with X = {F, W, M} for sub-modes Full, Window and MinMax</i>		
			LDL	RPCMIPS3WLXyyymmddhhmn_XXXXX.TAB	MIP_SPECTRUM_L_PO_X.FMT
				<i>with X = {F, W} for sub-modes Full and Window</i>	
		Passive	SDL	RPCMIPS3ESXyyymmddhhmn_XXXXX.TAB	MIP_SPECTRUM_P_PO_X.FMT
				<i>with X = {F, W, P} for sub-modes Full, Window and Power</i>	
			LDL	RPCMIPS3ELXyyymmddhhmn_XXXXX.TAB	MIP_SPECTRUM_P_PO_X.FMT
				<i>with X = {W, P} for sub-modes Window and Power</i>	
E-field Phase spectrum	Active	SDL	RPCMIPS3HSFyyymmddhhmn_XXXXX.TAB	MIP_SPECTRUM_S_SS_PH.FMT	
		LDL	RPCMIPS3HLFyyymmddhhmn_XXXXX.TAB	MIP_SPECTRUM_L_PH.FMT	

	Housekeeping parameters	All	RPCMIPSH3XXyymmddhhmn_XXXXX.TAB	MIP_CALIBRATED_HK.FMT
	Operational parameters	All	RPCMIPS3XXyymmddhhmn_XXXXX.TAB	MIP_CONFIG_TABLE.FMT
L5	Electron density (derived from RPC-MIP measurements)	Active (SDL + LDL)	RPCMIPS5DXyymmddhhmn_XXXXX.TAB	MIP_DENSITY.FMT
	Electron density (derived from the cross-calibration between RPC-MIP and RPC-LAP measurements)	MIP: Active SDL LAP: selected operational macros	RPCMIPLAPS5yyyymmddhhmn_XXXXX.TAB	MIPLAP_PLASMA_DENSITY.FMT

**Table 5:** RPC-MIP dataset naming convention.

Where *yymmddhhmn* is the start of observation and *XXXXX* is the duration (in minutes).

The time standards used in the RPC-MIP data products are:

- the Orbiter On-Board Time (OOBT, counter having a resolution of 1/65536 sec and based on the spacecraft High Frequency Clock)
- the UTC

For power measurements, sub-modes have been separated into different data files. As telemetry capacities were high during the whole mission, FULL sub-mode has always been operated. It gives the more complete set of information available on-board for one spectrum and must then be considered as the primary data file to be investigated.

In passive modes, power is coded on-board over 2 bits (0 to 20 dB) or 4 bits (0 to 60 dB), resulting in 2 dB or 4 dB digitization steps (integer values), respectively. In active modes the power is coded on 8 bits (0 to 64 dB) giving 0.25 dB digitization steps. However, the power values are always listed as ASCII\_REAL with format F7.2 in order to have the same format in different data files.

In passive modes the effective length of antenna is needed in order to obtain the electrical field in appropriate units. However, obtaining the effective length of the antenna is not trivial and is subject to discussion, this length depending on the characteristics of the plasma.

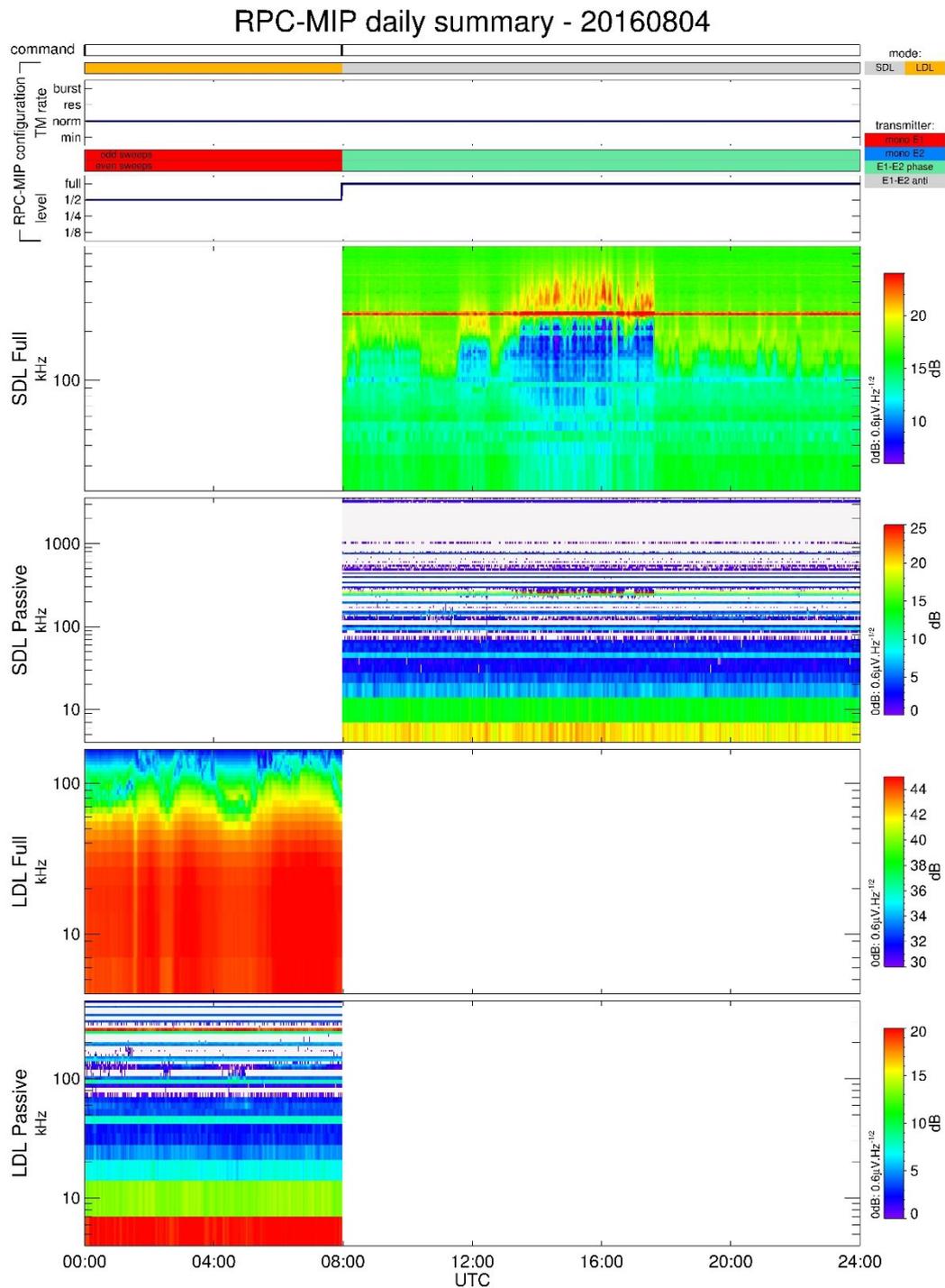
Power values are always given in decibels (dB) relative to  $0.6 \mu\text{V}\cdot\text{Hz}^{-1/2}$ .

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## 8.2 Browse files

Daily plots are provided as PNG files in the archive, with the following naming convention: `RPCMIPP5XX_yymmddhhmn_xxxx.PNG`. They are available in the BROWSE directory of L3 datasets. An example is given in figure 3 for August 4<sup>th</sup>, 2016. This summary plot gives information on operational parameters and shows 24-hour daily active and passive power spectrograms for SDL and LDL, as separate frames. Operational parameters include time of command (upper bar), SDL/LDL mode, TM rate, transmitter configuration (transmission mode and level). Each spectrogram is color-coded (independently from frame to frame) and presented as a 2D function of time and frequency. The frequency axis is in log scale to allow the large frequency dynamics in SDL to be represented. Note the operational mode change at 08:00 as indicated by the black mark in the “command” bar and by the changes in the operational parameters.

To ease a fast selection of the RPC-MIP data, browse files are also presented to the user in the PSA Rosetta archives search web interface.



Produced by LPC2E, CNRS/Universit  d'Orl ans

RPC-MIP is part of the Rosetta Plasma Consortium (RPC) of the ESA Rosetta mission

**Figure 3:** Example of a 24-hour browse file, for August 4<sup>th</sup>, 2016. Figure shows, from top to bottom: instrument operations parameters (HK), power spectrogram in SDL active mode, power spectrogram in SDL passive mode, power spectrogram in LDL active mode and power spectrogram in LDL passive mode.

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### 8.3 Instrument operations datasets

Configuration tables provide technical information regarding the instrument operational mode. The corresponding files can be found in the CALIBRATED directory of L3 datasets with the naming convention `RPCMIPS3XXXyymmddhhmn_XXXXX.TAB`. Each line in the file gives the technical parameters contained in the TC sent from ground to program the instrument. Information is given in a human readable format. One record is created in the file for each configuration change.

Figure 3 top panel shows the RPC-MIP operational configuration for August 4<sup>th</sup>, 2016. Information is color-coded or given as line plots to highlight mode changes. Change in operational parameters can have an impact on data time resolution, sensitivity and can influence the instrument response (when changing transmitter configuration or when switching between SDL and LDL for instance).

### 8.4 House keepings dataset

House keepings information produced on-board is given as a dedicated dataset with the naming convention `RPCMIPH3XXXyymmddhhmn_XXXXX.TAB`. It contains parameters such as reduced information on spectra (power averaged in LF and HF part of the bandwidth) or the temperature of the R2 electrode.

### 8.5 Power datasets

Active and passive data files in L3 datasets contain values of on-board measured power spectra (in dB) when RPC-MIP is operated in active SDL mode, active LDL mode and in passive mode. Data for each sub-mode are given in separate files (see Table 5) but the file format is common to all sub-modes. Each line of the file corresponds to one spectrum acquisition and gives the information listed below.

- Universal time
- On-board time
- Mode, possible values are : SURVEY or SWEEP (for active SDL), LDL (for active LDL) or PASSIVE (for passive SDL or LDL)
- Sub-mode, possible values are FULL, POWER, MINMAX, WINDOW
- Spectrum\_type (always equal to "POWER")
- $N$  values of frequency (in kHz)
- $N$  values of power (in dB)

The number of frequencies and power values ( $N$ ) in each spectrum depends on the instrument mode and sub-mode. The table below gives the number of values for each mode and sub-mode. More details are provided in Appendix A.2.

<i>Mode</i>	<i>Sub-mode</i>	<i>N</i>
SURVEY/SWEEP (SDL)	FULL	92
	WINDOW	14
	MINMAX	4
LDL	FULL	24
	WINDOW	15
PASSIVE	FULL	96
	WINDOW	48
	POWER	2

**Table 6:** Number of acquired values for spectra in RPC-MIP power dataset.

SDL Full and SDL Passive panels in figure 3 show examples of power spectrogram in SDL active and passive mode, respectively. Spectra values in dB are color-coded and given versus time and frequency. Time fluctuations of the power spectral response give information about the probed plasma and can be related to comet activity and/or trajectory effects. Depending on the plasma condition at the Rosetta probe location, the temporal evolution of the plasma frequency can sometimes be extracted from this spectrogram and corresponds to blue/yellow transition seen on the power spectrogram of figure 3, with clear enhancements after 12:00.

Interferences have been observed in RPC-MIP data since the beginning of the mission, resulting in artificial peaks in the RPC-MIP spectra. The main interference, located at 266 kHz, is clearly seen as a high amplitude red horizontal line in the SDL Full frame of figure 3. Passive spectrograms usually show very few amplitude variations, except for a number of known interferences (horizontal lines) and a special treatment is needed to extract useful information. An example is given in the next section (figure 4).

LDL Full and LDL Passive frames give the same information than SDL Full and Passive, when RPC-MIP is operated in LDL mode. Note that SDL and LDL modes differ in time resolution, as well as in frequency resolution and range. Note also that, due to the specific transmitter configuration in LDL, the shape of the spectral response is different than in SDL mode.

## 8.6 Phase datasets

Phase data files in L3 dataset contain values of on-board measured phase spectra (in degree) when RPC-MIP is operated in active (SDL or LDL) modes. Data for each mode are given in separate files (see Table 5) but the file format is common to all modes. Each line in the file corresponds to one phase spectrum acquisition and gives the information listed below.

- Universal time.
- On-board time.
- Mode, possible values are SURVEY, SWEEP (for active SDL) or LDL (for active LDL).
- Sub-mode (always equal to “FULL”).
- Spectrum\_type (always equal to “PHASE”).
- $N$  values of frequency (in kHz).
- $N$  values of phase (in deg).

The number of frequencies and power values ( $N$ ) in each spectrum depends on the instrument mode and is given in the table below. More details are provided in Appendix A.2.

<b>Mode</b>	<b>Sub-mode</b>	<b><math>N</math></b>
SURVEY/SWEEP (SDL)	FULL	28
LDL	FULL	24

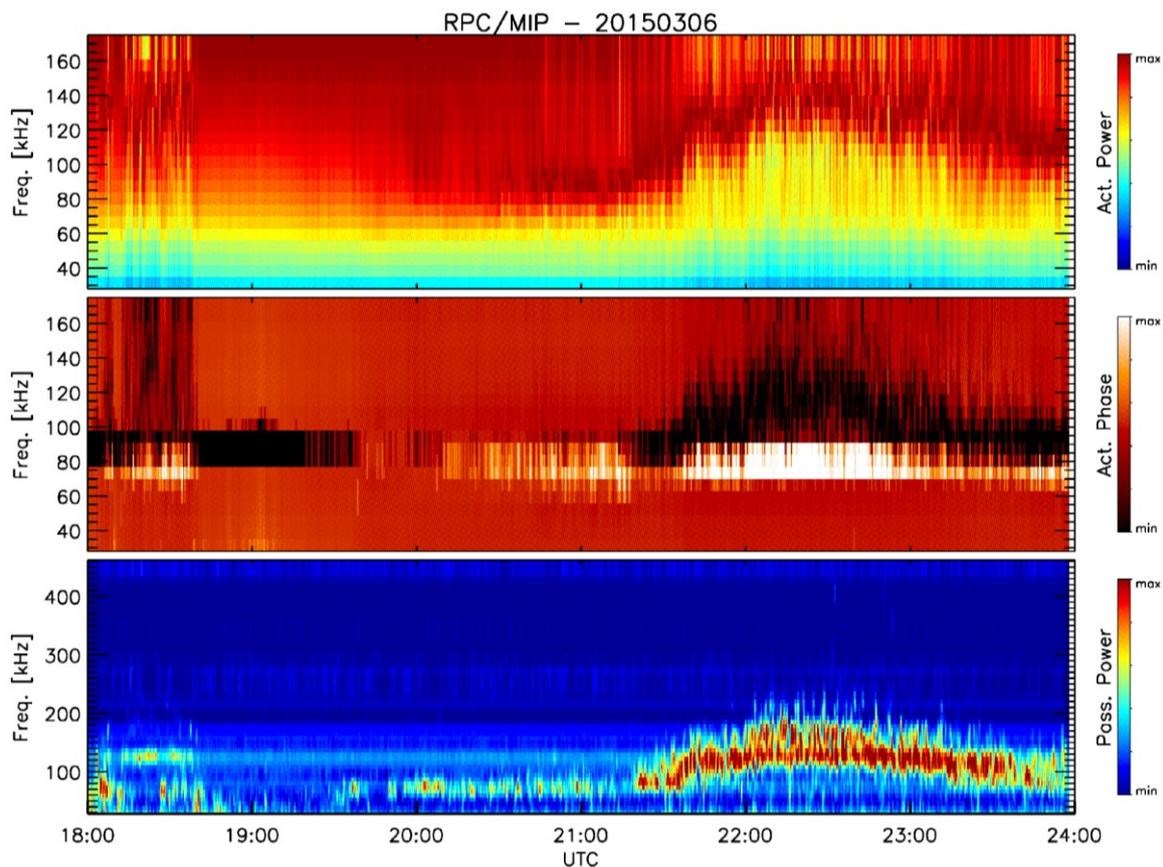
**Table 7:** Number of spectra values in RPC-MIP phase dataset.

In LDL mode of operations, the frequency table is fixed and 24 values are transmitted for the phase, as for power spectra. In SDL mode of operations, only a fraction of the on-board computed phase spectrum is kept in the data packets. From the 92 spectral measurements computed on-board at the 92 frequency values, only 28 phase values are transmitted, corresponding to frequencies centered on the resonance detected on-board. This results in a varying frequency domain for SDL phase information from time to time.

Note that all phase values are given modulo 360, leading to artificial phase jumps whenever phase values go below 0 deg or above 360 deg.

Figure 4 shows an illustrative example of active power, phase and passive power datasets for March 6<sup>th</sup>, 2015, when the instrument was operated in LDL mode. Data have been specifically processed to remove interferences and intrinsic noise. Each spectrum has been normalized individually in order to highlight temporal variations (thus losing time continuity of the spectral amplitude in the color scale). This example highlights the consistency of temporal variations between the 3 datasets during the time interval 21:00 and 24:00 (note that the

frequency range is larger for passive data). Temporal variations are thought to be related to temporal evolution of the plasma frequency that can be clearly identified on the 3 datasets as the maximum amplitude in power spectra (top panel), phase jumps in phase spectra (middle panel) and maximum amplitude in passive power spectra (bottom panel).



**Figure 4:** Case study of plasma line for March 6<sup>th</sup>, 2015. From top to bottom: LDL active power spectrogram, LDL active phase spectrogram, LDL passive power spectrogram. Data have been processed to remove artificial effects and intrinsic noise and spectra have been normalized individually (as indicated by the min/max labels on the color scales).

## 8.7 Electron density datasets

### 8.7.1 RPC-MIP electron density dataset

The RPC-MIP electron density, as a derived product, is provided in L5 datasets. Data files contain values of the total electron density derived from RPC-MIP power and phase spectra (when possible) when RPC-MIP is operated in active SDL or LDL mode. The extraction process is discussed in section 6.1. Each line of the file corresponds to one electron density value obtained from a single spectrum and gives the information listed below.

- UTC time of the electron density value.
- Half of the on-board acquisition time.
- Plasma electron density value (in  $\text{cm}^{-3}$ ).
- Estimated uncertainty of the plasma electron density (in  $\text{cm}^{-3}$ ).
- Quality of the plasma frequency signature in the RPC-MIP spectrum (between 0 and 1).
- Quality describing the RPC-MIP spectrum complexity (between 0 and 1).
- Density detection rate in a 320 seconds window.
- UTC time of the spectrum used to extract the electron density.
- Instrument mode at the time of acquisition (SDL or LDL).
- Instrument transmission level.
- Instrument telemetry rate.

Operational parameters included in L5 dataset potentially affect the estimation process and/or quality by e.g. modifying the instrument frequency response or signal-to-noise ratio. They are repeated in L5 datasets to enable investigations on electron density without the need for L3 datasets.

Note that the times corresponding to a RPC-MIP spectrum and to the associated derived electron density are different: RPC-MIP spectra are dated at the start of acquisition while the time associated to the electron density is the time of the spectrum from which the density is extracted, corrected from half the acquisition period due to on-board processing such as transmission at different frequencies and averaging over successive spectra (which is also given in L5 datasets). The acquisition period is operational mode dependent and varies in particular with the instrumental mode and the TM rate.

RPC-MIP SDL and LDL modes enable to probe plasmas with different Debye length ranges, below a few tens of centimeters or up to  $\sim 2\text{m}$ , respectively. When switching between SDL and LDL modes in a steady plasma, the extraction of the electron density estimation from the mutual impedance spectra in both operational modes cannot always be guaranteed, as one of the modes may not be adapted to perform a proper RPC-MIP measurement. Nevertheless, when mutual impedance spectra from both SDL and LDL modes allow the plasma density to be extracted, the plasma density does evolve continuously with time, as expected. Finally, the user should be aware that such SDL/LDL switches were not performed automatically, but instead triggered by TC defined before the scheduled operations. Furthermore, the frequency range in the LDL mode of operation is limited and does not extend beyond 168 kHz. It is quite usual than, in the comet environment, plasma frequency (thus electron density) exceeds this limit. The instrument mode of operation at the time of the density extraction is provided for each density value.

### 8.7.2 RPCMIP/RPCLAP electron density dataset

RPCMIP/RPCLAP cross-calibrated plasma density, as a derived product, is provided in L5 datasets. Data files contain values of the total plasma density derived from the cross-calibration of RPC-MIP densities (contained in RPC-MIP density dataset) and several possible RPC-LAP measurements. On-board operational constraints or instruments limits do not enable to perform the cross-calibration process over the whole mission in a continuous manner. Thus, only selected time intervals are included in this dataset. The cross-calibration process is briefly discussed in section 6.2 and more details can be found in RD4. While cross-calibration process is mainly driven by RPC-LAP operational modes and performed by RPC-LAP operational blocks, data files enclosed in this dataset are given as daily files for consistency with RPC-MIP density dataset. Each line of the file gives several information listed below.

- UTC time of the derived electron density value (sampled on RPC-LAP timings).
- Plasma density value (in  $\text{cm}^{-3}$ ).
- Quality value (normalized) of the inputs used for the cross-calibration process.
- Quality describing the cross-calibration process (TBD).
- RPC-MIP operational mode.
- RPC-MIP instrument telemetry rate.
- RPC-LAP measurements used as input for the cross-calibration process (current or potential mode and used LAP probe).
- RPC-LAP operational macro.

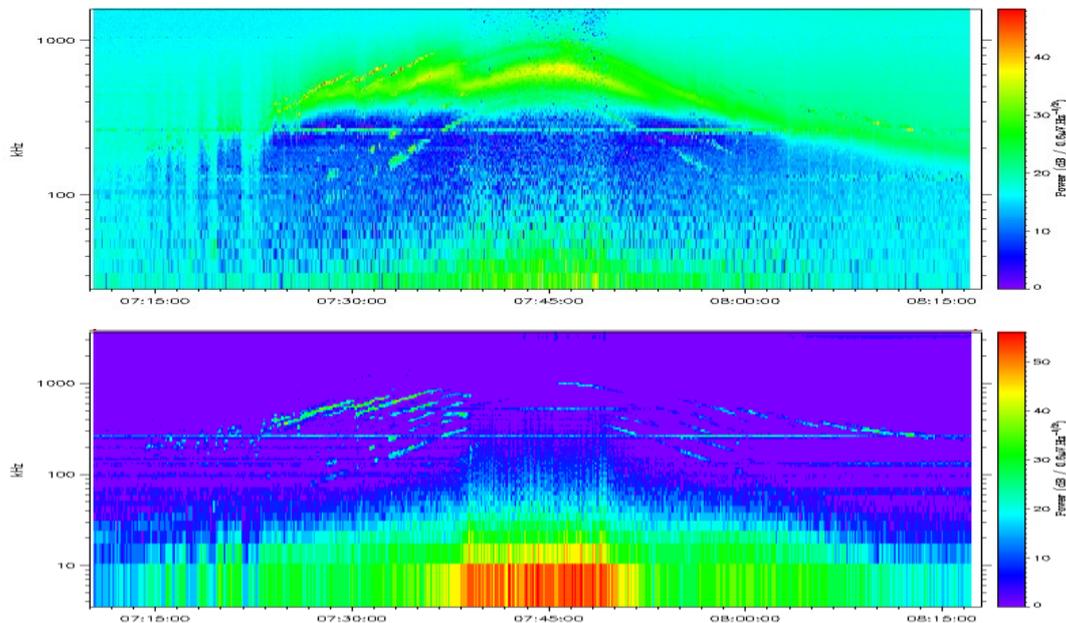
## 9. Recommendations and caveats

### 9.1 General recommendations on RPC-MIP datasets

RPC-MIP data are usually presented as dynamic spectrograms in which the electric-field intensity is plotted as a function of time (in the X-axis) and frequency (in the Y-axis) using a color code. The spectrograms bear important information about explored regions or cometary activity. The characteristic signature of natural or actively triggered waves indicates the nature of the ambient plasma regime and, combined with the spacecraft position, reveals the position of key boundaries encountered during a specific time interval.

It is therefore strongly recommended to first look at these spectrograms when using RPC-MIP observed and derived data. In some cases, RPC-MIP spectra may be corrupted by interferences and/or overflows that make the measurements interpretation intricate. Useful supporting parameters are included in the data file to help the user in the data analysis.

The following example shows the active and passive spectrograms for about 2 hours around the closest approach of Earth Swing-By #3. Values for the electric field power spectral density are expressed in dB and color-coded.



**Figure 5:** Active (top) and passive (bottom) spectrograms for RPC-MIP on November 13<sup>th</sup>, 2009 (Earth Swing-By #3) between 07:10 and 08:20.

## 9.2 Data quality

For **L3 datasets** (CALIBRATED data), a quality index is given in the label file (.LBL) file associated to each data file. Possible values are:

-1	not yet qualified
0	Good quality (number of reliable points > 75%)
1	Acceptable quality (number of reliable points > 50% and < 75%)
2	Bad quality (number of reliable points < 50%)

It is highly recommended to pay special attention to data analysis when encountering every other value than 0.

For **L5 datasets** (DERIVED data), each electron density record is associated with an estimated uncertainty and several quality indexes. These supporting parameters are estimated together with the electron density value, as part of the derivation or cross-calibration process.

- For RPC-MIP density datasets, three quality indexes are provided for each density value:

- (i) A normalized local quality of the plasma frequency signature in the spectrum that describes the signal-to-noise ratio of the signature.
  - (ii) A normalized complexity factor of the spectrum. This parameter is related to the number of candidate signatures to be identified as the plasma signature by the density derivation algorithm. A value close to 1 indicates a simple spectrum with a unique set of expected features.
  - (iii) A normalized detection rate giving the number of density values derived by the algorithm in 320 seconds (10 instrument cycles). A low detection rate denotes a limited efficiency of the algorithm during the 320 seconds periods. In this case, the user should keep in mind that RPC-MIP densities will not fully describe the plasma dynamics.
- For RPCMIP/RPCLAP cross-calibrated density datasets, two quality indexes are provided for each density value (more details can be found in RD4):
    - (i) A normalized quality of the inputs of the cross-calibration process, taken into consideration the quality of the RPC-MIP data and the quality of the RPC-LAP measurements.
    - (ii) A normalized quality describing the cross-calibration process.

The user is strongly encouraged to always consider these quality indexes and their potential impact on data analysis (e.g. averaging relevance).

### 9.3 Interferences

RPC-MIP suffers from a number of interferences that have been observed since the beginning of the mission. Both passive and active spectrograms are affected by a high level of interference, located at 266 kHz, at 49 kHz-harmonics and 800 kHz. The interference at 266 kHz is clearly seen as a horizontal line in the SDL Full panel of figure 3.

These interferences are believed to be related to the on-board electronics and are steady over the mission lifetime in frequency but may vary in amplitude in part due to the variation of the plasma environment and the antenna temperature (where the RPC-MIP preamplifier is located).

### 9.4 Caveats on R2 receiver temperature

A thermistor located in the R2 RPC-MIP electrode provides temperature measurements with a 32 seconds time resolution. Artificial features have been observed since the beginning of the mission, especially at low temperatures. Periodic peaks and squares are observed on the temperature curves, presumably due to on-board electronic device. An example is shown in Fig.6, second panel. One has to note that the type of features observed (peaks or squares) is dependent on the telemetry rate and on the mode (SDL or LDL) of the RPC-MIP instrument. However, the reason for these features is currently unknown.

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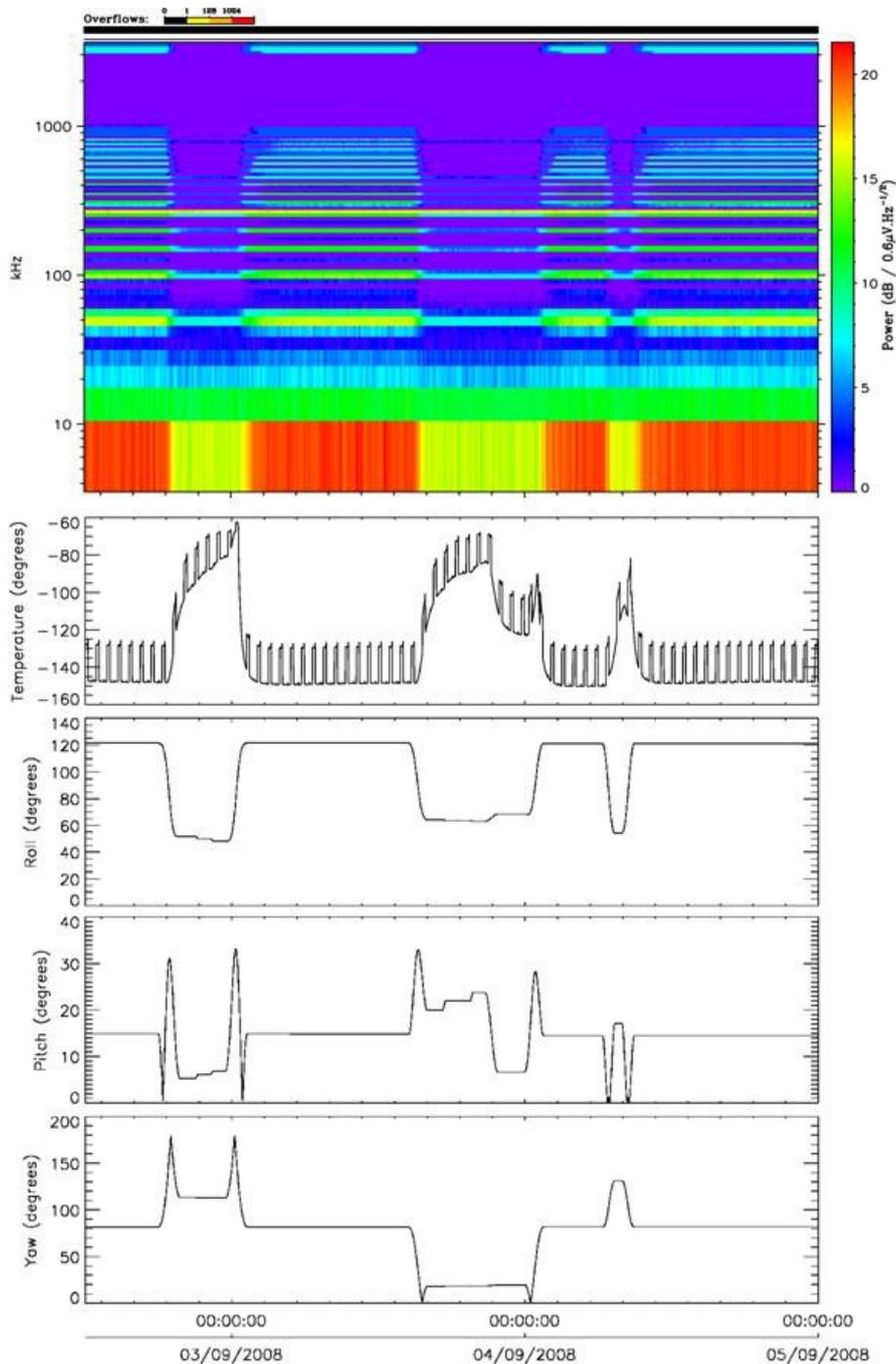
Moreover, the temperature value given by the R2 thermistor should be handled with care since, at the comet, surrounding conditions are not necessarily fully compatible with the nominal operating range of the thermistor, between  $-150^{\circ}$  and  $+100^{\circ}$ . This parameter is included in the HK RPC-MIP dataset.

## 9.5 Temperature effect on the preamplifier response

Since the beginning of the mission, it has been observed that the electric field power spectral density is affected at low temperatures, both in passive and active modes. This is due to the influence of the preamplifier temperature on its gain, which affects the overall response of the instrument over the whole frequency range and strengthens interferences level.

It may also be observed that the response of RPC-MIP is affected by small temperature variations when the antenna is operating well in its operational temperature range, especially since about April-May 2015.

Figure 6 below illustrates the temperature effect on the passive spectrogram obtained by RPC-MIP around 2008 September 04. The color-coded passive spectrogram (top panel) exhibits a higher level of noise and interferences when the temperature is lower (second panel). The last three panels are attitude angles (roll, pitch, yaw) showing the correlation between the probe attitude and the temperature on the RPC-MIP sensor.



**Figure 6:** From top to bottom: RPC-MIP spectrogram, R2 temperature and spacecraft attitude angles.

In order to avoid misguided interpretation of the RPC-MIP measurements, the user is invited to check the power spectral temporal variations against temporal variation of the R2 temperature or against orbital positions and attitude variations, available on the PSA server (under the Ancillary Data section).

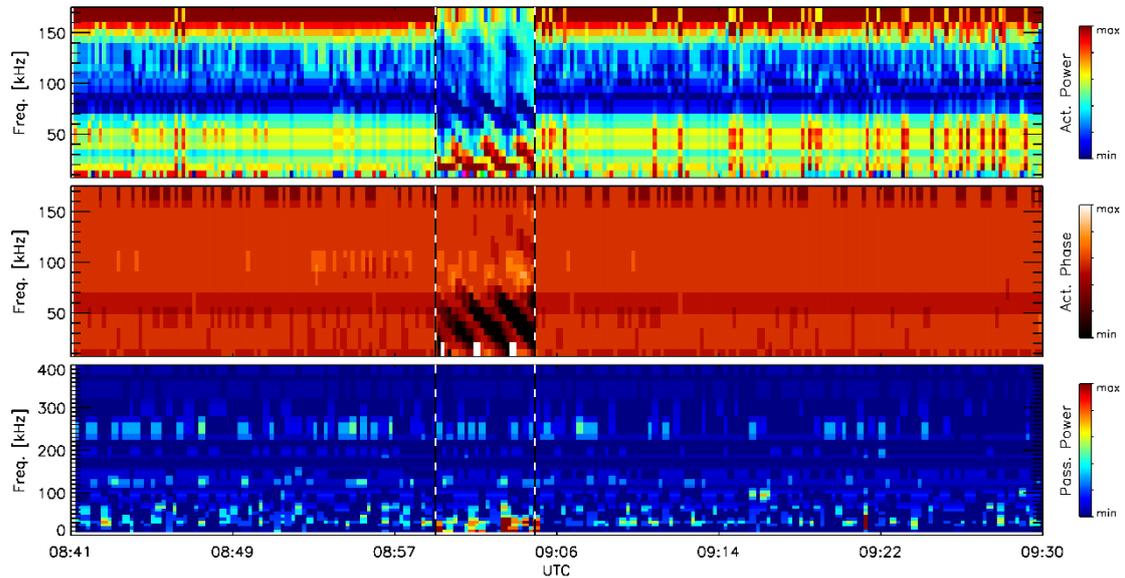
## 9.6 Caveats on thrusters activations

Spacecraft thrusters activations perturb the surrounding medium and thus may lead to artefacts in the RPC-MIP response. Different effects have been observed all along the mission lifetime. Most prominent effects are observed during the orbit correction manoeuvres (OCM) that were ran routinely to correct the spacecraft attitude or orbit and when the instrument is in LDL mode of operations. Figures 7 and 8 show two examples of perturbations in the data acquired by RPC-MIP during OCMs. These figures present active power and phase spectrograms and passive power spectrogram that have been processed to highlight the temporal fluctuations of the measured plasma characteristics. The vacuum response has been subtracted and each spectrum has been normalized individually. Vertical black and white dashed lines mark the starting time and ending time of the corresponding OCM. While on figure 7, structured features are clearly seen in the power and phase spectrograms in active mode, the perturbation in figure 8 seems to be different in nature, appearing as highly dynamical noise. Both perturbation perfectly match the time of the OCMs but no clear reason has been found to explain the different features.

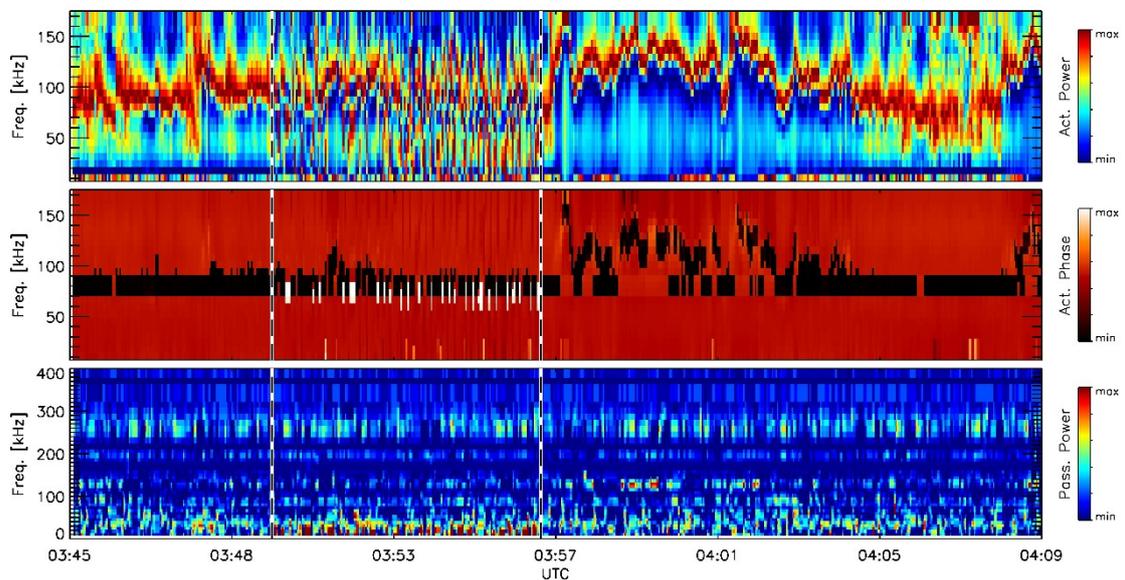
While not fully systematic, most of the OCMs induce perturbations (either as structured features as in figure 7 or as noise as in figure 8) in the active power and phase data when RPC-MIP is in LDL mode. Note also that a perturbation is observed on passive spectrograms, increasing the noise level of a (limited) number of low frequency channels. This is also observed when the instrument is operated in SDL mode. However, no clear effect could be identified on active measurements in SDL mode.

The duration of these perturbations is directly related to the thrusters activation, ranging from a couple of minutes to 15 minutes.

Wheel Off Loading (WOL) events have also been investigated but no notable effect has been observed on RPC-MIP measurements.



**Figure 7:** Processed RPC-MIP data (from top to bottom: power spectrogram in active, phase spectrogram in active, power spectrogram in passive) acquired on Aug 3<sup>rd</sup>, 2014 in LDL mode of operations. Vertical black and white dashed lines mark the start time and end time of an OCM.



**Figure 8:** Processed RPC-MIP data (from top to bottom: power spectrogram in active, phase spectrogram in active, power spectrogram in passive) acquired on June 24<sup>th</sup>, 2015 in LDL mode of operations. Vertical black and white dashed lines mark the start time and end time of an OCM.

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## 9.7 Notes on RPC-MIP electron density

Electron density estimates are extracted from RPC-MIP spectra or by cross-calibration between RPC-MIP densities and RPC-LAP measurements by ad-hoc algorithms. While the overall quality is thought to be good, these algorithms cannot prevent false detections. The user should consider checking the electron density against the signatures observed in active power and phase spectra. The user is also invited to take into account the uncertainty and quality parameters that are derived from the spectra characteristics and are provided in the L5 dataset for each individual record.

Due to the instrumental characteristics, it is not always possible to determine a plasma density value. First, the plasma frequency, from which the electron density is inferred, can exceed the instrument frequency range, especially in the LDL mode of operations. In this specific case (LDL), RPC-MIP cannot retrieve plasma densities above about  $350 \text{ cm}^{-3}$ . Second, RPC-MIP is blind to the plasma if the Debye length is larger than the typical transmitter-receivers distance. Practically, the signature at the plasma frequency is of the order of, or below, the noise level of the receiver in this regime, and therefore can be undetectable (or undetected) by the algorithms designed to find a well-defined resonance signature at the plasma frequency in the RPC-MIP spectra. This implies that RPC-MIP cannot retrieve densities below a given value that depend on the operated mode and the electron temperature itself.

The plasma environment of comet 67P/CG has been observed to be very dynamical, with large amplitude plasma density, and therefore plasma frequency, variations on time scales ranging from 10's of seconds to hours. Moreover, the influence of the cometary ionosphere large-scale inhomogeneities is observed on density, and therefore plasma frequency, variations on time scales typically ranging from few hours (for instance related to comet rotation) to days (for instance related to spacecraft trajectory). For these two reasons, part of the plasma frequency line can be above the frequency detection limit. A blind low frequency filter (or time-windowed average) or a blind statistical study can then result in bad estimation of the actual averaged plasma behaviour and in misleading interpretations. Temporal variations of electron density or frequency plasma line can be checked on RPC-MIP active spectrograms provided as BROWSE images to check and remove for out-of-bounds events when doing such studies. Furthermore, the instrumental lower and upper detection limits, in term of electron density, is given in the electron density dataset, for each record.

## 9.8 Reference systems

As the instrument measures scalar parameters, there is no coordinate systems transformation needed to analyse RPC-MIP data.

All information on orbital and attitude parameters of the Rosetta orbiter in the different heliocentric or cometocentric coordinate systems is available on the PSA server (under the Ancillary Data section).

## 10. References

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- Trotignon J. G., Michau, J.-L., Lagoutte D., et al. (2007), RPC-MIP: The Mutual Impedance Probe of the Rosetta Plasma Consortium, *Space Science Rev*, 128, 7133-728. <https://doi.org/10.1007/s11214-006-9005-1>

## A.1 Appendix 1: RPC-MIP frequency tables

The table given in this appendix describes the different frequency tables used in active SDL, active LDL and passive modes. Some of the frequency tables are pseudo-logarithmic with frequency bins gradually increasing in width and have been designed to allow flexibility in the instrument's range, without a priori knowledge of the encountered medium.

All tables in active SDL mode contain 92 frequency bins. The effective operating table is selected by telecommand.

Note that among the pre-defined active SDL tables, **nominal 0** and **complementary 5** have been used most of the time during the comet phase of the Rosetta mission. In active LDL mode, a unique frequency table exists. This is also the case for passive mode.

Frequency table		Bandwidth [kHz]	Resolution [kHz]	Number of steps
Active	SDL Nominal 0	28-224	7	29
		238-448	14	16
		479-869	28	16
		952-1792	56	16
		1904-3472	112	15
Active	SDL Complementary 1	28-665	7	92
Active	SDL Complementary 2	259-896	7	92
Active	SDL Complementary 3	518-1792	14	92
Active	SDL Complementary 4	924-3472	28	92
Active	SDL Complementary 5	28-343	7	46
		357-987	14	56
Active	SDL Complementary 6	28-224	7	29
		238-630	14	29
		658-1582	28	34
Active	SDL Complementary 7	266-896	14	46
		924-2184	28	46
Active	LDL	7-168	7	24
Passive		7-224	7	32
		238-448	14	16
		479-896	28	16
		952-1792	56	16
		1904-3584	112	16

## A.2 Appendix 2: RPC-MIP data content per sub-mode

The table given in this appendix describes the different sub-modes of the RPC-MIP instrument. Each sub-mode is related to an on-board process that acquires a full spectrum and transmit all or part of the information in the data packet, depending on the available TM rate.

<i>RPC-MIP sub-mode</i>	<i>File Contents</i>
Survey/Sweep Full	<b>Power</b> 92 values (all frequency bins)
	<b>Phase</b> 28 values (selection of frequency bins) corresponding to $[f_{max}-13, f_{max} +14]$ where $f_{max}$ is the frequency of the maximum of the power spectrum
Survey/Sweep Window	<b>Power</b> 14 values (selection of frequency bins) corresponding to $[f_{max}-3, f_{max} +10]$ where $f_{max}$ is the frequency of the maximum of the power spectrum
	<b>Phase</b>
Survey/Sweep MinMax	<b>Power</b> 4 values (selection of frequency bins) corresponding to the frequency of two highest maxima and the two lowest minima of the power spectrum
	<b>Phase</b>
LDL full	<b>Power</b> 24 values (all frequency bins)
	<b>Phase</b> 24 values (all frequency bins)
LDL Window	<b>Power</b> 15 values (selection of frequency bins) corresponding to $[f_{max}-3, f_{max} +11]$ where $f_{max}$ is the frequency of the maximum of the power spectrum
	<b>Phase</b>
Passive Full	<b>Power</b> 96 values (all frequency bins)
	<b>Phase</b>
Passive Window	<b>Power</b> 48 values (selection of frequency bins) corresponding to 32 values in [7-224] kHz and 16 values in [238-448] kHz
	<b>Phase</b>
Passive Power	<b>Power</b> 2 values corresponding to the mean power value in [7-448] kHz and the mean value in [479-3584] kHz
	<b>Phase</b>

### A.3 Appendix 3: RPC-MIP operational sequences

Details about sub-modes contained in each RPC-MIP sequence are given in the following tables for each telemetry rate. In SDL mode of operations, several sequences have been defined. They consist in combinations of different sub-modes corresponding to different objectives. For instance, sequence #7 has been designed as a pure passive sequence. All sequences have not been implemented for each TM rate. The number of the sequence can be found in the “configuration tables” product of the RPC-MIP archive. In LDL mode of operations, a unique sequence has been designed. See section 4.1 for information contained in each sub-mode.

Information retrieved from each sub-mode is actually the result of several on-board acquisitions and averaging. The number of averaged spectra and duration of the process is given in the tables below in column **# averaged**, as well as the corresponding overall duration in column **Duration (s)** (in seconds).

The start time of each sub-mode is given in seconds after the start time of the sequence. Note that sub-modes are not necessarily continuous as idle periods exist within a sequence. Note also that the duration of a RPC-MIP sequence is always fixed to 32 seconds, including transmission time to RPC-PIU and idle periods after acquisitions thus leading in irregular time resolutions over several sequences.

In the tables below, the grey lines correspond to on-board acquisitions in active mode that are not transmitted in the TM. They drive the automatic selection of the frequency table of the following Sweep sub-modes. They will not appear in the data files but are mentioned here to keep track of active periods.

#### A.3.1 Minimum telemetry rate

Sequence		Sub-Mode	Start time after sequence start (s)	Duration (s)	# averaged	not in TM
SDL 0		Survey Full	0	5.75	8	
		Passive Power	5.75	0.5	8	
SDL 1		Survey Full	0	2.875	4	x
		Sweep Window	2.875	2.875	4	
		Passive Power	5.75	0.5	8	
SDL 2		Survey Full	0	0.725	1	x
		Sweep Window	0.725	5.75	8	
		Passive Power	6.475	0.5	8	
SDL 3 to 6		<i>not implemented</i>				
SDL 7	16x	16x Passive Power	0 ; 0.5 ; 1 ; 1.5 ; 2 ; 2.5 ; 3 ; 3.5 ; 4 ; 4.5 ; 5 ; 5.5 ; 6 ; 6.5 ; 7 ; 7.5	0.5	8	
LDL 0		LDL Window	0	6.02	32	
		Passive Power	6.02	0.93	8	

### A.3.2 Normal telemetry rate

Sequence		Sub-Mode	Start time after sequence start (s)	Duration (s)	# averaged	not in TM
SDL 0		Survey Full	0	5.75	8	
		Passive Power	5.75 ; 21.65	0.5	8	
		Survey MinMax	7.95 ; 15.90 ; 23.85	5.75	8	
		Passive Full	13.70	0.5	8	
SDL 1	4x	Survey Full	0 ; 7.95 ; 15.90 ; 23.85	2.875	4	x
	3x	Sweep Full	2.875 ; 10.825 ; 18.775	2.875	4	
	2x	Passive Power	5.75 ; 21.65	2.875	8	
		Passive Full	13.70	2.875	8	
		Sweep MinMax	26.725	2.875	4	
SDL 2	4x	Survey Full	0 ; 7.825 ; 15.65 ; 23.725	0.725	1	x
		Sweep Full	0.725	5.75	8	
	2x	Passive Power	6.475 ; 22.125	0.25	4	
	3x	Sweep MinMax	8.55 ; 16.375 ; 24.45	5.75	8	
		Passive Full	14.3	0.25	4	
SDL 3		Survey Window	0	2.875	4	
		Passive Full	2.875	0.25	4	
	7x	Survey Full	3.725 ; 7.455 ; 11.185 ; 14.915 ; 18.645 ; 22.375 ; 26.105	1.44	2	x
	7x	Sweep Window	5.165 ; 8.895 ; 12.625 ; 16.355 ; 20.085 ; 23.815 ; 27.545	1.44	2	
	7x	Passive Power	6.605 ; 10.335 ; 14.065 ; 17.795 ; 21.525 ; 25.255 ; 28.985	0.25	4	
SDL 4		Survey Full	0	11.5	16	
		Passive Full	11.5	0.93	16	
		Survey Window	15.63	11.5	16	
		Passive Power	27.13	0.93	16	
SDL 5	9x	Survey Window	0 ; 3.125 ; 6.60 ; 10.075 ; 13.55 ; 17.025 ; 20.50 ; 29.975 ; 27.45	2.875	4	
		Passive Full	2.875	0.25	4	
SDL 6	Not implemented					
SDL7	4x	Passive Full	0 ; 8.03 ; 16.06 ; 24.09	1.83	32	
LDL 0	3x	LDL Full	0 ; 10.65 ; 21.30	6.02	32	
	2x	Passive Window	6.02 ; 16.67	0.93	16	

### A.3.3 Burst telemetry rate

<i>Sequence</i>		<i>Sub-Mode</i>	<i>Start time after sequence start (s)</i>	<i>Duration (s)</i>	<i># averaged</i>	<i>not in TM</i>
<b>SDL 0</b>	7x	Survey Full	0 ; 4.38 ; 8.76 ; 13.14 ; 17.52 ; 21.90 ; 26.28	1.44	2	
	6x	Passive Power	1.44 ; 5.82 ; 9.67 ; 14.58 ; 18.96 ; 23.34	0.25	4	
	6x	Survey MinMax	2.19 ; 6.57 ; 10.95 ; 15.33 ; 19.71 ; 24.09	1.44	2	
	6x	Passive Full	3.63 ; 8.01 ; 12.39 ; 16.77 ; 21.15 ; 25.53	0.24	4	
<b>SDL 1</b>	6x	Survey Full	0 ; 4.42 ; 8.84 ; 13.26 ; 17.68 ; 22.10 ; 26.52	0.73	1	x
	6x	Sweep Full	0.73 ; 5.15 ; 9.57 ; 13.99 ; 18.41 ; 22.83 ; 27.25	0.73	1	
	6x	Passive Power	1.46 ; 5.88 ; 10.30 ; 14.72 ; 19.14 ; 23.56	0.25	4	
	6x	Sweep MinMax	2.94 ; 7.36 ; 11.78 ; 16.20 ; 20.62 ; 25.04	0.73	1	
	6x	Passive Full	3.67 ; 8.09 ; 12.51 ; 16.93 ; 21.35 ; 25.77	0.25	4	
<b>SDL 2</b>		Survey Full	0	1.44	2	
		Passive Full	1.44	0.25	4	
	7x	Survey Window	2.29 ; 6.02 ; 9.75 ; 13.48 ; 17.21 ; 20.94 ; 24.67	1.44	2	
	7x	Sweep Full	3.73 ; 7.46 ; 7.46 ; 11.19 ; 14.92 ; 18.65 ; 22.38 ; 26.11	1.44	2	
	7x	Passive Power	5.17 ; 8.90 ; 12.63 ; 16.36 ; 20.09 ; 23.82 ; 27.55	0.25	4	
<b>SDL 3 to 6</b>		Not implemented				
<b>SDL 7</b>	24x	Passive Full	0 ; 1.2 ; 2.4 ; 3.6 ; 4.8 ; 6.0 ; 7.2 ; 8.4 ; 9.6 ; 10.8 ; 12.0 ; 13.2 ; 14.4 ; 15.6 ; 16.8 ; 18.0 ; 19.2 ; 20.4 ; 21.6 ; 22.8 ; 24.0 ; 25.2 ; 26.4 ; 27.6	0.5	8	
<b>LDL 0</b>	11x	LDL Full	0 ; 2.65 ; 5.30 ; 7.95 ; 10.60 ; 13.25 ; 15.90 ; 18.55 ; 21.20 ; 23.85 ; 26.50	0.75	4	
	10x	LDL Window	1.30 ; 3.95 ; 6.60 ; 9.25 ; 11.90 ; 14.55 ; 17.20 ; 19.85 ; 22.50 ; 25.15	0.8	4	
	20	Passive Window	0.75 ; 2.10 ; 3.40 ; 4.75 ; 6.05 ; 7.40 ; 8.70 ; 10.05 ; 11.35 ; 12.70 ; 14.0 ; 15.35 ; 16.65 ; 18.0 ; 19.30 ; 20.65 ; 21.95 ; 23.30 ; 24.60 ; 25.95 ; 27.25	0.25	4	

## A.4 Appendix 4: Item values for dataset name formation

The table below gives information used for dataset naming convention for the different mission phases. The grey lines correspond to periods with no RPC-MIP data: the instrument was off during those phases and no corresponding dataset is therefore available on the PSA.

Mission phases start dates and end dates are defined by the project in RD3. Note that RPC-MIP time coverage can differ as the instrument was not switched on continuously during pre-comet phases of the mission.

<i>Mission phase</i>	<i>Start date</i>	<i>End date</i>	<i>&lt;target name&gt;</i>	<i>&lt;target id&gt;</i>	<i>&lt;abbreviation&gt;</i>
COMMISSIONING 1	2004-03-05	2004-06-06	CAL	CAL	CVP1
CRUISE 1	2004-06-07	2004-09-05	CAL	CAL	CR1
COMMISSIONING 2	2004-09-06	2004-10-16	CAL	CAL	CVP2
EARTH SWING-BY 1	2004-10-17	2005-04-04	EARTH	E	EAR1
CRUISE 2	2005-04-05	2006-07-28	CAL	CAL	CR2
MARS SWING-BY	2006-07-29	2007-05-28	MARS	M	MARS
CRUISE 3	2007-05-29	2007-09-12	CAL	CAL	CR3
EARTH SWING-BY 2	2007-09-13	2008-01-27	EARTH	E	EAR2
CRUISE 4-1	2008-01-28	2008-08-03	CAL	CAL	CR4A
STEINS FLY-BY	2008-08-04	2008-10-05	STEINS	A	AST1
CRUISE 4-2	2008-10-06	2009-09-13	CAL	CAL	CR4B
EARTH SWING-BY 3	2009-09-14	2009-12-13	EARTH	E	EAR3
CRUISE 5	2009-12-14	2010-05-16	CAL	CAL	CR5
LUTETIA FLY-BY	2010-05-17	2010-09-03	LUTETIA	A	AST2
RENDEZVOUS MANOEUVRE 1	2010-09-04	2011-06-07	CAL	CAL	RVM1
CRUISE 6	2011-06-08	2014-01-20	CAL	CAL	CR6
PRELANDING	2014-01-21	2014-07-22	67P	C	PRL1
PRELANDING	2014-07-25	2014-10-16 up to 11:00	67P	C	PRL2
PRELANDING	2014-10-16 from 14:00	2014-11-18	67P	C	PRL3
COMET ESCORT 1	2014-11-19	2015-03-10	67P	C	ESC1
COMET ESCORT 2	2015-03-11	2015-06-30	67P	C	ESC2
COMET ESCORT 3	2015-07-01	2015-10-21	67P	C	ESC3
COMET ESCORT 4	2015-10-22	2015-12-31	67P	C	ESC4
ROSETTA EXTENSION 1	2016-01-01	2016-04-05	67P	C	EXT1
ROSETTA EXTENSION 2	2016-04-06	2016-06-30	67P	C	EXT2
ROSETTA EXTENSION 3	2016-07-01	2016-09-30	67P	C	EXT3

Authorized values for *<target id>* are:

- CAL (calibration)
- E (Earth)
- M (Mars)
- A (Asteroid)
- C (Comet)

## A.5 Appendix 5: OCM events and effect on RPC-MIP data

The table given in this appendix lists the start time and end time of OCM during the mission when RPC-MIP was operating. The operational mode (SDL or LDL transmission as well as TM rate: normal mode NM or burst mode BM) is given for each event.

Effect of OCMs on passive spectrogram is almost systematically observed, but with a limited impact.

Tick marks indicate events for which a perturbation is clearly observed also on active spectrograms (power and phase). Note that the perturbation can be different from one event to the other and that the signature also depends on TM rate.

Grey lines indicate events with no clear perturbation on RPC-MIP spectra.

Start	End	Mode		Impact on active measurements
2008/09/04_07:26:00.247	2008/09/04_07:27:44.374	SDL	NM	
2014/08/03_09:00:03.740	2014/08/03_09:13:15.740	SDL	NM	
2014/08/06_09:00:01.053	2014/08/06_09:06:27.165	LDL	NM	✓
2014/08/10_09:00:00.453	2014/08/10_09:06:24.830	SDL	NM	
2014/08/13_09:00:00.460	2014/08/13_09:06:22.119	SDL	NM	
2014/08/17_09:00:00.468	2014/08/17_09:06:18.571	SDL	NM	
2014/08/20_09:00:00.366	2014/08/20_09:05:46.504	SDL	NM	
2014/08/24_09:00:00.230	2014/08/24_09:05:07.390	SDL	NM	
2014/08/27_09:00:00.219	2014/08/27_09:05:02.517	SDL	NM	
2014/08/31_09:00:00.236	2014/08/31_09:05:03.805	SDL	NM	
2014/09/03_09:00:00.211	2014/09/03_09:04:54.998	LDL	NM	✓
2014/09/07_09:00:00.077	2014/09/07_09:04:17.520	SDL	BM	
2014/09/10_08:59:59.675	2014/09/10_09:02:28.713	SDL	NM	
2014/09/14_08:59:59.279	2014/09/14_09:00:30.562	SDL	NM	
2014/09/17_08:59:59.631	2014/09/17_09:01:22.878	LDL	NM	✓
2014/09/17_10:39:59.672	2014/09/17_10:41:24.783	SDL	BM	
2014/09/21_08:59:59.256	2014/09/21_09:00:23.641	SDL	NM	
2014/09/24_08:59:59.211	2014/09/24_09:00:20.111	SDL	NM	
2014/09/29_08:59:59.774	2014/09/29_09:01:37.459	SDL	NM	
2014/10/01_11:34:59.243	2014/10/01_11:35:18.328	LDL	NM	✓
2014/10/05_09:09:59.290	2014/10/05_09:10:13.406	SDL	NM	
2014/10/08_08:59:59.303	2014/10/08_09:00:43.337	SDL	NM	
2014/10/12_09:09:59.337	2014/10/12_09:10:27.542	SDL	NM	
2014/10/15_09:09:59.417	2014/10/15_09:11:00.712	SDL	NM	
2014/10/19_08:59:59.216	2014/10/19_09:00:15.496	SDL	NM	
2014/10/22_08:59:59.217	2014/10/22_09:00:15.510	SDL	NM	

2014/10/28_12:59:59.441	2014/10/28_13:01:20.537	SDL	NM	
2014/10/31_02:09:58.710	2014/10/31_02:11:30.210	SDL	NM	
2014/11/03_09:09:58.937	2014/11/03_09:10:06.152	SDL	NM	
2014/11/09_01:34:59.058	2014/11/09_01:35:03.813	SDL	NM	
2014/11/12_06:05:00.444	2014/11/12_06:11:12.924	LDL	NM	✓
2014/11/16_05:59:58.801	2014/11/16_06:04:23.909	SDL	NM	
2014/11/16_07:39:58.812	2014/11/16_07:44:20.298	SDL	NM	
2014/11/19_00:59:58.991	2014/11/19_01:01:23.186	SDL	BM	
2014/11/22_00:59:59.127	2014/11/22_01:00:08.264	SDL	NM	
2014/11/29_01:09:59.090	2014/11/29_01:10:06.112	SDL	NM	
2014/12/03_00:59:59.053	2014/12/03_01:00:50.109	SDL	NM	
2014/12/06_00:59:59.090	2014/12/06_01:00:32.679	SDL	NM	
2014/12/10_00:59:59.158	2014/12/10_01:00:11.713	SDL	NM	
2014/12/17_00:59:59.109	2014/12/17_01:00:09.054	LDL	NM	✓
2014/12/20_00:59:59.097	2014/12/20_01:00:18.797	SDL	NM	
2014/12/24_01:09:58.962	2014/12/24_01:10:36.429	LDL	NM	
2014/12/27_12:59:59.094	2014/12/27_13:00:06.208	SDL	NM	
2014/12/31_00:59:59.082	2014/12/31_01:00:03.095	SDL	NM	
2015/01/14_00:59:59.107	2015/01/14_01:00:08.874	LDL	NM	
2015/01/17_00:59:59.111	2015/01/17_01:00:04.948	LDL	NM	
2015/01/24_00:59:59.090	2015/01/24_01:00:03.118	SDL	NM	
2015/02/04_00:59:58.851	2015/02/04_01:03:48.558	LDL	NM	✓
2015/02/07_01:00:00.849	2015/02/07_01:05:05.770	SDL	NM	
2015/02/07_02:40:00.324	2015/02/07_02:43:30.376	SDL	NM	
2015/02/11_01:00:00.357	2015/02/11_01:03:35.627	SDL	NM	
2015/02/14_01:00:01.714	2015/02/14_01:07:27.290	LDL	NM	✓
2015/02/17_01:00:01.838	2015/02/17_01:07:43.861	SDL	NM	
2015/02/18_01:00:00.927	2015/02/18_01:05:06.259	LDL	NM	✓
2015/02/21_01:00:00.442	2015/02/21_01:03:41.955	SDL	NM	
2015/02/25_01:11:04.804	2015/02/25_01:15:14.765	SDL	NM	
2015/02/28_01:00:00.735	2015/02/28_01:04:28.015	LDL	BM	✓
2015/03/04_01:00:00.518	2015/03/04_01:03:50.372	LDL	BM	✓
2015/03/07_01:00:00.661	2015/03/07_01:04:13.152	SDL	NM	
2015/03/11_00:59:59.256	2015/03/11_01:04:11.624	SDL	NM	
2015/03/14_00:59:59.265	2015/03/14_01:04:11.622	LDL	NM	✓
2015/03/18_00:59:59.270	2015/03/18_01:04:11.726	LDL	NM	✓
2015/03/21_00:59:59.346	2015/03/21_01:03:36.188	SDL	NM	
2015/03/25_00:59:59.326	2015/03/25_01:04:35.001	SDL	NM	
2015/03/28_00:59:59.321	2015/03/28_01:07:08.151	LDL	BM	✓
2015/04/04_00:59:59.527	2015/04/04_01:06:15.936	SDL	BM	
2015/04/08_12:59:59.386	2015/04/08_13:04:53.014	SDL	BM	
2015/04/11_01:09:59.097	2015/04/11_01:12:40.042	LDL	BM	✓

2015/04/15_00:59:59.434	2015/04/15_01:04:43.238	SDL	BM	
2015/04/22_00:59:59.556	2015/04/22_01:05:44.229	SDL	BM	
2015/05/06_01:39:59.468	2015/05/06_01:45:06.968	SDL	NM	
2015/05/13_01:39:59.360	2015/05/13_01:45:17.790	LDL	BM	✓
2015/05/20_01:39:59.541	2015/05/20_01:44:49.313	SDL	NM	
2015/05/23_01:39:59.104	2015/05/23_01:44:19.903	LDL	BM	
2015/05/27_13:49:59.278	2015/05/27_13:56:56.812	LDL	BM	✓
2015/06/03_01:39:59.582	2015/06/03_01:45:19.605	SDL	BM	
2015/06/10_01:39:59.488	2015/06/10_01:44:03.967	LDL	BM	✓
2015/06/17_01:39:59.544	2015/06/17_01:44:43.618	SDL	BM	
2015/06/17_03:49:24.987	2015/06/17_03:55:45.128	SDL	BM	
2015/06/20_01:39:59.906	2015/06/20_01:45:53.523	LDL	BM	✓
2015/06/20_03:49:59.596	2015/06/20_03:54:36.127	LDL	BM	✓
2015/06/24_01:39:59.667	2015/06/24_01:44:42.408	LDL	BM	✓
2015/06/24_03:49:59.570	2015/06/24_03:56:37.877	LDL	BM	✓
2015/06/27_01:39:59.682	2015/06/27_01:46:29.767	SDL	BM	
2015/06/27_03:49:59.740	2015/06/27_03:54:42.008	SDL	BM	
2015/07/01_01:49:59.335	2015/07/01_01:51:40.423	SDL	BM	
2015/07/04_01:39:59.644	2015/07/04_01:44:21.845	LDL	BM	✓
2015/07/04_03:49:59.565	2015/07/04_03:54:14.274	LDL	BM	✓
2015/07/08_01:49:59.224	2015/07/08_01:51:06.724	LDL	BM	
2015/07/11_01:39:59.647	2015/07/11_01:44:10.549	SDL	BM	
2015/07/11_03:49:59.615	2015/07/11_03:54:19.410	SDL	BM	
2015/07/15_01:49:59.149	2015/07/15_01:51:50.046	SDL	BM	
2015/07/18_01:39:59.790	2015/07/18_01:44:22.220	LDL	BM	✓
2015/07/18_03:49:59.572	2015/07/18_03:54:07.697	LDL	BM	
2015/07/22_01:49:59.172	2015/07/22_01:50:35.586	LDL	BM	x
2015/07/25_01:49:59.540	2015/07/25_01:54:01.159	SDL	BM	
2015/07/29_01:39:59.715	2015/07/29_01:45:26.570	SDL	BM	
2015/08/01_01:49:59.841	2015/08/01_01:55:29.038	SDL	BM	
2015/08/05_01:39:59.748	2015/08/05_01:43:20.415	SDL	BM	
2015/08/08_01:39:59.709	2015/08/08_01:43:13.036	SDL	BM	
2015/08/12_01:49:59.802	2015/08/12_01:54:51.294	SDL	NM	
2015/08/15_01:49:59.426	2015/08/15_01:54:13.930	SDL	BM	
2015/08/19_01:39:59.202	2015/08/19_01:43:33.906	LDL	BM	✓
2015/08/22_01:49:58.722	2015/08/22_01:54:06.522	SDL	BM	
2015/08/26_01:39:58.519	2015/08/26_01:46:41.611	SDL	BM	
2015/08/29_01:49:58.860	2015/08/29_01:55:16.860	SDL	BM	
2015/09/02_01:49:58.856	2015/09/02_01:58:09.965	SDL	BM	
2015/09/05_01:49:59.061	2015/09/05_01:59:56.710	SDL	BM	
2015/09/09_01:39:59.195	2015/09/09_01:46:00.078	SDL	BM	
2015/09/12_01:49:58.397	2015/09/12_01:55:34.799	SDL	BM	

2015/09/16_01:39:59.313	2015/09/16_01:47:43.527	SDL	BM	
2015/09/23_01:39:59.115	2015/09/23_01:49:53.427	SDL	BM	
2015/09/30_01:39:59.284	2015/09/30_01:50:57.703	SDL	BM	
2015/09/30_03:49:59.378	2015/09/30_03:58:24.268	SDL	BM	
2015/10/03_01:39:59.286	2015/10/03_01:40:50.331	SDL	BM	
2015/10/07_01:39:59.324	2015/10/07_01:46:50.380	SDL	BM	
2015/10/14_01:39:59.384	2015/10/14_01:44:08.612	SDL	BM	
2015/10/17_01:39:59.484	2015/10/17_01:44:31.682	SDL	BM	
2015/10/21_01:39:59.540	2015/10/21_01:47:01.179	SDL	BM	
2015/10/24_01:49:59.466	2015/10/24_01:58:07.373	SDL	BM	
2015/10/31_01:39:59.644	2015/10/31_01:46:59.610	SDL	BM	
2015/11/04_01:39:59.517	2015/11/04_01:45:50.647	LDL	BM	✓
2015/11/07_01:39:59.752	2015/11/07_01:46:01.949	SDL	BM	
2015/11/11_01:49:59.669	2015/11/11_01:55:00.726	SDL	BM	
2015/11/14_01:49:59.730	2015/11/14_01:55:00.192	SDL	BM	
2015/11/18_01:49:59.201	2015/11/18_01:53:48.609	SDL	BM	
2015/11/21_01:39:59.666	2015/11/21_01:44:59.972	SDL	BM	
2015/11/25_01:39:59.566	2015/11/25_01:44:12.447	SDL	BM	
2015/11/28_01:39:59.681	2015/11/28_01:44:28.578	SDL	BM	
2015/12/02_01:39:59.471	2015/12/02_01:43:42.367	SDL	BM	
2015/12/05_01:49:59.651	2015/12/05_01:53:28.253	SDL	BM	
2015/12/09_01:49:59.814	2015/12/09_01:53:58.361	SDL	BM	
2015/12/12_01:39:59.625	2015/12/12_01:43:28.401	SDL	BM	
2015/12/16_01:39:59.647	2015/12/16_01:43:56.300	SDL	BM	
2015/12/19_01:39:59.633	2015/12/19_01:43:31.249	SDL	BM	
2015/12/23_01:39:59.599	2015/12/23_01:43:06.475	SDL	BM	
2015/12/26_01:49:59.603	2015/12/26_01:52:36.789	SDL	BM	
2015/12/30_01:49:59.811	2015/12/30_01:53:15.188	SDL	BM	
2016/01/02_01:39:59.612	2016/01/02_01:43:05.912	SDL	BM	
2016/01/06_01:39:59.644	2016/01/06_01:43:09.064	SDL	BM	
2016/01/09_01:39:59.519	2016/01/09_01:42:21.463	SDL	BM	
2016/01/13_01:39:59.515	2016/01/13_01:42:34.970	SDL	BM	
2016/01/16_01:39:59.757	2016/01/16_01:44:22.723	SDL	BM	
2016/01/16_03:49:59.481	2016/01/16_03:54:38.214	SDL	BM	
2016/01/20_01:39:59.419	2016/01/20_01:42:14.161	SDL	BM	
2016/01/23_01:39:59.475	2016/01/23_01:42:02.391	SDL	BM	
2016/01/27_01:39:59.479	2016/01/27_01:42:08.664	SDL	BM	
2016/01/30_01:39:59.494	2016/01/30_01:41:39.302	SDL	BM	
2016/02/03_01:39:59.684	2016/02/03_01:44:12.843	SDL	BM	
2016/02/03_03:49:59.677	2016/02/03_03:54:25.623	SDL	BM	
2016/02/06_01:39:59.428	2016/02/06_01:41:55.150	SDL	BM	
2016/02/10_01:39:59.466	2016/02/10_01:41:58.984	SDL	BM	

2016/02/13_01:39:59.921	2016/02/13_01:44:24.618	SDL	BM	
2016/02/13_03:49:59.783	2016/02/13_03:54:21.236	SDL	BM	
2016/02/17_01:39:59.951	2016/02/17_01:44:10.136	SDL	BM	
2016/02/17_03:49:59.799	2016/02/17_03:54:20.799	SDL	BM	
2016/02/20_01:39:59.353	2016/02/20_01:40:49.657	SDL	BM	
2016/02/24_01:49:59.283	2016/02/24_01:51:18.059	SDL	BM	
2016/02/27_01:39:59.309	2016/02/27_01:40:28.271	SDL	BM	
2016/03/02_01:39:58.855	2016/03/02_01:40:16.674	SDL	BM	
2016/03/05_01:39:58.931	2016/03/05_01:40:26.563	SDL	BM	
2016/03/09_01:39:58.875	2016/03/09_01:40:19.544	SDL	BM	
2016/03/12_01:49:58.893	2016/03/12_01:50:20.528	SDL	BM	
2016/03/16_01:40:58.715	2016/03/16_01:41:20.504	SDL	BM	
2016/03/19_01:50:58.692	2016/03/19_01:51:15.177	SDL	BM	
2016/03/23_01:50:00.229	2016/03/23_01:57:54.169	SDL	BM	
2016/03/26_01:40:01.137	2016/03/26_01:54:43.607	SDL	BM	
2016/03/30_13:40:00.449	2016/03/30_13:57:32.288	SDL	BM	
2016/04/02_13:39:59.613	2016/04/02_13:53:08.633	SDL	BM	
2016/04/06_01:40:00.672	2016/04/06_01:48:05.500	SDL	BM	
2016/04/09_01:40:00.654	2016/04/09_01:47:14.294	SDL	BM	
2016/04/11_13:50:01.182	2016/04/11_13:57:52.388	SDL	BM	
2016/04/13_01:40:00.133	2016/04/13_01:44:09.313	SDL	BM	
2016/04/17_01:39:59.834	2016/04/17_01:43:18.110	SDL	BM	
2016/04/20_01:49:59.735	2016/04/20_01:52:26.362	SDL	BM	
2016/04/24_01:39:58.752	2016/04/24_01:40:19.863	SDL	BM	
2016/05/04_01:39:58.832	2016/05/04_01:40:36.766	SDL	BM	
2016/05/08_01:39:59.181	2016/05/08_01:40:01.407	SDL	BM	
2016/05/11_01:39:58.746	2016/05/11_01:40:55.733	SDL	BM	
2016/05/15_01:39:58.679	2016/05/15_01:40:14.192	SDL	BM	
2016/05/18_13:39:58.555	2016/05/18_13:40:23.837	SDL	BM	
2016/05/22_01:49:58.360	2016/05/22_01:50:34.360	SDL	BM	
2016/05/25_01:39:58.557	2016/05/25_01:40:24.529	SDL	NM	
2016/06/01_01:39:59.546	2016/06/01_01:41:20.738	SDL	NM	
2016/06/05_01:49:59.461	2016/06/05_01:51:58.213	SDL	NM	
2016/06/08_01:50:45.070	2016/06/08_01:52:55.832	SDL	NM	
2016/06/08_03:49:58.490	2016/06/08_03:50:24.291	SDL	NM	
2016/06/12_01:39:58.156	2016/06/12_01:41:23.152	SDL	NM	
2016/06/12_03:49:59.561	2016/06/12_03:52:46.175	SDL	NM	
2016/06/15_01:46:22.020	2016/06/15_01:52:23.620	LDL	BM	✓
2016/06/15_03:49:59.656	2016/06/15_03:51:56.907	SDL	BM	
2016/06/19_01:49:58.038	2016/06/19_01:51:39.939	SDL	NM	
2016/06/22_01:39:58.288	2016/06/22_01:40:55.049	SDL	NM	
2016/06/29_01:39:58.543	2016/06/29_01:40:29.706	SDL	NM	

2016/07/13_01:39:58.998	2016/07/13_01:40:04.335	LDL	NM	
2016/07/17_01:49:58.259	2016/07/17_01:50:59.875	SDL	NM	
2016/07/20_01:49:59.243	2016/07/20_01:50:00.743	SDL	NM	
2016/07/27_01:39:58.029	2016/07/27_01:41:21.091	SDL	BM	
2016/07/31_01:39:58.520	2016/07/31_01:40:20.656	SDL	NM	
2016/08/03_01:39:58.888	2016/08/03_01:40:10.234	SDL	NM	
2016/08/10_08:59:46.220	2016/08/10_09:00:12.559	SDL	NM	
2016/08/12_08:59:44.783	2016/08/12_09:00:13.933	SDL	NM	
2016/08/13_08:59:43.939	2016/08/13_09:00:14.724	LDL	NM	
2016/08/15_08:59:45.127	2016/08/15_09:00:13.627	SDL	NM	
2016/08/16_08:59:49.853	2016/08/16_09:00:09.018	LDL	NM	
2016/08/18_08:59:50.944	2016/08/18_09:00:07.933	SDL	NM	
2016/08/19_08:59:50.926	2016/08/19_09:00:07.948	LDL	NM	
2016/08/21_08:59:53.272	2016/08/21_09:00:05.578	SDL	NM	
2016/08/22_08:59:51.381	2016/08/22_09:00:07.491	LDL	NM	
2016/08/24_08:59:53.760	2016/08/24_09:00:05.051	SDL	BM	
2016/08/25_09:04:52.698	2016/08/25_09:05:06.198	LDL	NM	
2016/08/27_08:59:54.847	2016/08/27_09:00:03.994	SDL	NM	
2016/08/28_09:04:52.922	2016/08/28_09:05:05.968	SDL	NM	
2016/08/30_08:59:52.697	2016/08/30_09:00:06.197	SDL	NM	
2016/08/31_08:59:51.995	2016/08/31_09:00:06.882	SDL	NM	
2016/09/02_08:59:47.454	2016/09/02_09:00:11.385	SDL	NM	
2016/09/03_08:59:49.276	2016/09/03_09:00:09.578	SDL	NM	
2016/09/05_08:59:49.908	2016/09/05_09:00:08.965	SDL	NM	
2016/09/06_08:59:51.677	2016/09/06_09:00:07.189	LDL	NM	
2016/09/08_09:04:53.776	2016/09/08_09:05:05.035	SDL	BM	
2016/09/09_08:59:45.701	2016/09/09_09:00:13.066	LDL	NM	
2016/09/11_09:04:41.863	2016/09/11_09:05:16.680	SDL	NM	
2016/09/12_09:04:50.764	2016/09/12_09:05:08.104	SDL	NM	
2016/09/14_08:59:51.737	2016/09/14_09:00:07.137	SDL	NM	
2016/09/15_08:59:50.454	2016/09/15_09:00:08.454	SDL	NM	
2016/09/17_08:59:51.560	2016/09/17_09:00:07.305	SDL	NM	
2016/09/18_09:04:50.730	2016/09/18_09:05:08.139	SDL	NM	
2016/09/20_08:59:40.924	2016/09/20_09:00:17.569	SDL	NM	
2016/09/21_08:59:35.146	2016/09/21_09:00:22.861	SDL	NM	
2016/09/23_09:04:52.645	2016/09/23_09:05:06.237	SDL	NM	
2016/09/24_09:04:08.205	2016/09/24_09:05:46.160	SDL	NM	
2016/09/26_08:59:10.901	2016/09/26_09:00:43.870	SDL	NM	
2016/09/28_02:19:55.003	2016/09/28_02:20:03.775	SDL	NM	
2016/09/29_20:48:10.079	2016/09/29_20:51:35.500	SDL	BM	

## A.6 Appendix 6: Instrumental and operational events

The table given in this appendix lists operational events that occurred during the mission with potential effect on the RPC-MIP data provided in the PSA archive.

Several types of events are indicated in the table:

- *PASSIVE*: this corresponds to error in LDL programming that occasionally led to situations with RPC-MIP ready in LDL mode but without transmission on RPC-LAP. In that cases, RPC-MIP acts as a single receiver and no transmission occurred, leading to fully passive measurements (including impedance spectra measurements labelled as active).
- *CAL*: this corresponds to in-flight calibration campaigns when the transmission configuration (transmission level and/or transmission configuration) was changed over a limited time period, thus impacting the received signal.
- *CAL\_ALOOP*: this corresponds to in-flight tests of the autoloop configuration. Corresponding data should not be used for science.

Start	End	Event
2008/09/06_06:38:31	2008/09/10_06:01:11	PASSIVE
2010/07/10_18:54:50	2010/07/12_07:00:42	PASSIVE
2014/12/20_09:05:39	2014/12/20_23:57:23	PASSIVE
2014/12/26_00:05:23	2014/12/26_23:57:23	PASSIVE
2014/12/28_08:05:23	2014/12/28_23:00:19	PASSIVE
2015/01/05_00:05:23	2015/01/05_23:57:23	PASSIVE
2015/01/07_00:05:23	2015/01/07_23:57:23	PASSIVE
2015/01/13_23:22:43	2015/01/14_23:57:23	PASSIVE
2015/06/24_23:15:00	2015/06/24_23:59:00	CAL
2015/08/20_03:55:00	2015/08/20_06:05:00	CAL
2015/09/10_11:30:00	2015/09/10_12:20:00	CAL
2015/09/16_05:55:00	2015/09/17_06:05:00	CAL
2015/11/27_21:05:00	2015/11/27_21:25:00	CAL
2015/12/09_12:00:00	2015/12/09_13:05:00	CAL
2016/02/03_00:00:00	2016/02/03_00:20:00	CAL_ALOOP
2016/02/03_12:15:00	2016/02/03_12:30:00	CAL_ALOOP
2016/03/16_00:00:00	2016/03/16_00:50:00	CAL
2016/03/16_06:00:00	2016/03/16_06:50:00	CAL
2016/03/16_12:00:00	2016/03/16_12:50:00	CAL
2016/03/19_16:00:00	2016/03/19_16:50:00	CAL
2016/03/20_04:00:00	2016/03/20_04:50:00	CAL
2016/03/20_16:00:00	2016/03/20_16:50:00	CAL
2016/03/21_04:00:00	2016/03/21_04:50:00	CAL
2016/03/21_16:00:00	2016/03/21_16:50:00	CAL

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2016/03/31_00:00:00	2016/03/31_01:30:00	CAL
2016/04/13_00:00:00	2016/04/13_12:00:00	CAL
2016/04/24_12:00:00	2016/04/24_14:30:00	CAL
2016/05/01_12:00:00	2016/05/01_14:30:00	CAL
2016/05/04_01:00:00	2016/05/07_21:00:00	CAL
2016/05/17_11:00:00	2016/05/17_22:00:00	CAL
2016/05/20_04:00:00	2016/05/20_08:00:00	CAL
2016/05/27_04:00:00	2016/05/27_08:00:00	CAL
2016/06/01_12:00:00	2016/06/01_15:00:00	CAL
2016/06/13_02:00:00	2016/06/13_05:00:00	CAL

Note that these events are also listed in the LOGBOOK provided in the RPC-MIP L3 datasets.