1 INTRODUCTION

The FIELDS instrumentation combines the most accurate 3D double probe electric field measurement yet assembled, a flight proven electron drift instrument, two precise fluxgate magnetometers, a set of electric and magnetic wave detectors, a digital signal processor, and a central digital processing unit in one integrated package in which time bases are coordinated, offset inter-determined, and in-flight calibration is performed. A variety of data products are produced from the FIELDS telemetry. Quicklook and Level 2 products that are specific to FIELDS components are described in other volumes of the MMS Data Product Guide. Quicklook and Level 2 products that rely on combinations of FIELDS components are described in this volume.

2 INSTRUMENTATION

2.1 Overview

FIELDS instrumentation is described in other volumes of the MMS Data Products Guide.

2.2 Science Background

2.3 Level-2 Science Requirements

2.4 Instrument Characteristics

Instrument characteristics for most components of FIELDS are described in other volumes. However, it is worth mentioning the significant effort expended to understand intricacies of time stamp to assure the highest accuracy possible. During the FIELDS Integration and Timing Test performed on each flight model, all analog and digital timing delays were measured and understood. This information is applied to all FIELDS telemetry processed from Level 0 to Level 1A on computers at the Science Data Center at LASP. Further processing is then performed at FIELDS member institutions.

2.5 Heritage

3 DATA PRODUCTS

Quicklook Products

Solitary waves can be an indicator of proximity to a reconnection event. The Solitary Wave Detector can sample either a pair axial or spin plane boom using a simple algorithm to "detect" a solitary wave event.

Level 2 Products

EPSD combines the low frequency E spectral density covering the frequency range of 1 to 8000 Hz and the medium frequency E spectral density covering the frequency range of .25 to 100 kHz.

BPSD is the low frequency B spectral density covering the frequency range of .2 to 6000 Hz.

Combined E is a time series electric field vector that is created by combining the double probe electric field measurement from ADP/SDP and the electron drift determination of the electric field from EDI.

Combined B is a time series magnetic field vector that is created by combining the DC magnetic field results from AFG and DFG with the AC magnetic field measurement from SCM.

Level 2 Solitary Wave is TBD

FIELDS Sample Times

The FIELDS CDPU receives a TAI time code and a Pulse Per Second (PPS) tone from the CIDP. The FIELDS CDPU latches the TAI time code and sets the coarse time to this whole second value at the arrival of the Time at the Tone Signal (PPS). The FIELDS CDPU has a free running clock that is used to define the fine time between the PPS tones. FIELDS data packets times are assigned with a combination of TAI (whole second) and FIELDS (fractional second) values.

The TAI and FIELDS clocks rates are different. A clock rate scaling factor (CRSF) between the TAI PPS and FIELDS clock is needed to accurately assign times to the data samples within each data packet. The clock rate scaling factor is approximated using the most frequent, routinely produced FIELDS packet is APID 0x105 packet, which is generated every 4 FIELDS clock seconds, as follows:

> Let T1 be the time tag of an APID 0x105 packet. T1 consists of C1 (the latched TAI whole second) and F1 (the fractional second from the FIELDS clock). The actual TAI time corresponding to the T1 time tag can be calculated as
>
> $$T1[TAI] = C1 + f * F1$$
>
> where f is the CRSF between the TAI and FIELDS clocks.
>
> Let T2 be the time tag of the subsequent packet consisting of C2 and F2 portions. The TAI time corresponding to the T2 time tag is
>
> $$T2[TAI] = C2 + f * F2$$

These consecutive packets are 4 FIELDS seconds apart, or 4×f in terms of the TAI clock. Subtracting the TAI times associated with these two packets we get:

```
4f = C2-C1 + f * (F2-F1)
```

Solving for the CRSF produces

```
f = (C2-C1)/(4-(F2-F1)) or DeltaC/(4-DeltaF)
```

The CDPU retrieval of the CIDP time code could be delayed by up to 35 microseconds due to the encoding of the PPS, Sun Crossing, and Delphi pulses by the CIDP on a single interface (CIDP_FIELDS_ICD). Also the oscillator frequency on the FIELDS CDPU clock is temperature dependent which can cause the rate to vary by 35 ppm over the temperature range. The rate scaling factor calculation above provides a first order correction for both of these artifacts. The scaling factor applied in FIELDS CDF files is averaged over 10 minutes.

Aside from temperature variation, FIELDS sample spacing should be constant. Therefore, the sample spacing is defined as the last packet time minus the first packet time in an interval divided by the number of samples. Sample times are adjusted by known digital timing delays, as confirmed in the FIELDS FIT test, are used to determine sample time:

```
sample_time[i] = reference_time + sample[i] * sample_interval - delay
```

Reference_time is the time tag of the first packet of an interval without mode change or data gap. If there is a gap in packet sequence count, reference time becomes the time tag of the first packet after the sequence count gap for subsequent samples.

Combined E Algorithm

Start with ADP/SDP Level 2 electric field and transform into DSL frame:

```
EX_DSL(t), EY_DSL(t), EZ_DSL(t)
```

Correct for offset using EDI electric field data that has been transformed into DSL frame:

```
EX_DSL_corr(t) = EX_DSL(t) + xoff(t)
EY_DSL_corr(t) = EY_DSL(t) + yoff(t)
EZ_DSL_corr(t) = EZ_DSL(t) + zoff(t)
```

For a particular EDI beam time, interpolate to beam time, t_beam:

```
EX_DSL_interp = interpol(EX_DSL_corr, t_ADP/SDP, t_beam)
EY_DSL_interp = interpol(EY_DSL_corr, t_ADP/SDP, t_beam)
EZ_DSL_interp = interpol(EZ_DSL_corr, t_ADP/SDP, t_beam)
```

Check “E dot B = 0”

Transform into B Perp Plane(BPP):

```
E_BPP = dsl2bpp * E_DSL
```

Calculate the drift step and “target” from the electric field:

V_drift = E_BPP XB / B^2
D = V_drift / T_gyro
T_BPP = “Target” = -D

Combined B Algorithm

Start with Level 2 DFG/AFG and Level 2 SCM data transformed into Mag123 coordinate system

FFT each component of DFG/AFG and SCM separately.

Correct phase and amplitude with calibration data. Also compute noise figure on sensitivity and error in phase correction.

Apply time offset correction ???? Should this already be done in Level 1 ???

Calibration already applied because using Level 2 data ????

Merge FFT components, weighted by respective errors:

Overlap region uses respective errors.
Above fH (<10 Hz) use only SCM
Below fL (~1 Hz) use only DFG/AFG

Inverse FFT

Despin to inertial coordinate system (which system??)

Spectral Density Algorithm

The DSP implements a 1024 point FFT algorithm onboard to create spectra data products. This algorithm produces 1024 separate frequency “bins” internally, however adjacent bins are averaged together to produce a smaller number of bins in the final data product. Spectral information reported by the DSP is arranged in a pseudo-log manner where bin size increase by frequency. The midpoints of each frequency bin are included in the CDF files. This onboard algorithm applies to the LFE, MFE, and LFB, which are the inputs to the L2 Magnetic Power Spectral Density (BPSD) and Electric Power Spectral Density (EPSD) data products.

Solitary Wave Detector Algorithm

Solitary waves can be an indicator of proximity to a reconnection event. The Solitary Wave Detector can sample either E12 or E34 or E56 (axial or spin plane booms). Onboard, it uses a simple algorithm (peak / pseudo-rms exceeds a threshold) to "detect" a solitary wave event. When one is found, we use the amplitude of the event to dump it into one of four bins. Each bin then contains literal counts of solitary wave detections. The bins have adjustable amplitude bounds. There are 4 bins, but it takes 5 threshold values to define 4 bins (a top and bottom value for each bin).

Science Parameters

L2 EPSD CDF (mms#_dsp_fast/slow_l2_epsd.cdf)

Name	**Type**
mms#_dsp_epsd_omni	CDF_REAL4[88]
mms#_dsp_epsd_x	CDF_ REAL4[88]
mms#_dsp_epsd_y	CDF_ REAL4[88]
mms#_dsp_epsd_z	CDF_ REAL4[88]

L2 BPSD CDF (mms#_dsp_fast/slow_l2_bpsd.cdf)

Name	**Type**
mms#_dsp_bpsd_omni	CDF_REAL4[56]
mms#_dsp_bpsd_scm1	CDF_REAL4[56]
mms#_dsp_bpsd_scm2	CDF_REAL4[56]
mms#_dsp_bpsd_scm3	CDF_REAL4[56]

Quicklook Solitary Wave CDF (mms#_adp/sdp_fast_ql_swd.cdf)

Name	**Type**
mms#_adp/sdp_swd_epoch	CDF_TIME_TT2000
mms#_adp/sdp_swd_bin0	CDF_INT2
mms#_adp/sdp_swd_bin1	CDF_INT2
mms#_adp/sdp_swd_bin2	CDF_INT2
mms#_adp/sdp_swd_bin3	CDF_INT2
mms#_adp/sdp_swd_thresh0	CDF_INT2
mms#_adp/sdp_swd_thresh1	CDF_INT2
mms#_adp/sdp_swd_thresh2	CDF_INT2
mms#_adp/sdp_swd_thresh3	CDF_INT2
mms#_adp/sdp_swd_thresh4	CDF_INT2

`mms#_adp/sdp_swd_binX: literal counts of solitary wave detections in amplitude X`

L2 E Combined CDF (mms#_fld_brst_l2_e.cdf)

Name	Type
mms#_fld_e_epoch	CDF_TIME_TT2000
mms#_fld_e_xyz_gse	CDF_FLOAT[3]

L2 B Combined CDF (mms#_fld_brst_l2_b.cdf)

Name	Type
mms#_fld_b_epoch	CDF_TIME_TT2000
mms#_fld_b_xyz_gse	CDF_FLOAT[3]

L2 Solitary Wave CDF (mms#_adp/sdp_fast_l2_swd.cdf)

Name	**Type**
mms#_adp/sdp_swd_epoch	CDF_TIME_TT2000
mms#_adp/sdp_swd_bin0	CDF_REAL4
mms#_adp/sdp_swd_bin1	CDF_REAL4
mms#_adp/sdp_swd_bin2	CDF_REAL4
mms#_adp/sdp_swd_bin3	CDF_REAL4