THEMIS
EFI Calibration Procedure

thm_soc_130_efi_calibration
March 21, 2011

1.0 Description of the THM_CAL_EFI procedure:

Note that THM_CAL_EFI is called by THM_LOAD_EFI by default, and that all calibration keywords are available from THM_LOAD_EFI. The following example loads raw data, and then calibrates.

Example:

```
timespan, '2008-08-16', /days
thm_load_efi, probe='a', level='l1', type='raw', /get_support_data
thm_cal_efi, probe='a'
```

The output of these commands will be in tplot variables 'tha_eff', 'tha_efp', 'tha_efw', ‘tha_vaf’,’tha_vap’, ‘tha_vaw’, ‘tha_vbf’, ‘tha_vbp’, and ‘tha_vbw’ for the given time range, calibrated and with the field variables (eff, efp, efw) in the DSL coordinate system (See ftp://apollo.ssl.berkeley.edu/pub/THEMIS/3%20Ground%20Systems/3.2%20Science%20Operations/Science%20Operations%20Documents/thm_soc_110_COORDINATES_20060929.pdf for descriptions of the different THEMIS coordinate systems. For the general description of the EFI instrument, see http://themis.ssl.berkeley.edu/instrument_efi.shtml .)

2.0 Steps in EFI calibration:

1) There are a number of different datatypes to be calibrated, voltages: vaf, vbf, vap, vbp, vaw, vbw; fields: eff, efp and efw. The voltages have 6 components, v1 to v6 for each variable; the fields have 3 components.

Each datatype is calibrated separately. For the fields, additional variables are created; ef?_0, which contains the field with the Z component (in DSL coordinates) set to zero; also ef?_dot0 which contains the field calculated using the assumption that E dot B = 0. The X and Y components are the same for all three variables.

For each datatype:

2) Gains and offsets are input from calibration files. Currently these are not time-dependent, but may vary from probe to probe, thus there is a different file for each probe. The calibration structure for voltage variables, v1 to v6 contains:

```
CAL_PAR_TIME    STRING    Array[1]      ;a time for the calibration, not yet used
GAIN            FLOAT     Array[1, 6]   ;gain factors, currently all 0.0032105, V/(ADC count).
OFFSET          LONG      Array[1, 6]   ;offset factors, all currently 0, ADC counts.
UNITS           STRING    Array[1]      ;V
```

For Electric field variables, the calibration structure contains, for e12, e34, e56:

```
CAL_PAR_TIME STRING Array[1]      ;a time for the calibration, not yet used
EDC_GAIN FLOAT Array[1, 3]        ;gain for DC coupled data, 0.000457771 for all axes,
                                  ;(AC or DC coupling information is contained in the
```

```
                                  ;header variable for each time interval.), V/(ADC count).
EAC_GAIN FLOAT Array[1, 3]        ;gain for AC coupled data, 7.75160e-05 for all three axes,
                                  ; V/(ADC count).
OFFSET LONG Array[1, 3]           ;offsets for each axis, in ADC units, 70, 113, 0 for E12,
                                  ;E34 ,E56, respectively
UNITS STRING Array[1]             ;mV/m
BOOM_LENGTH FLOAT Array[1, 3]     ;49.6 for boom 12, 40.4 for boom 34, 5.63 for boom 56
BOOM_SHORTING_FACTOR FLOAT Array[1, 3]  ;0.714 for booms12 and 34, 0.50 for boom 56
DSC_OFFSET FLOAT Array[1, 3]      ;2.5, 0, 0 for E12, E34 ,E56, respectively, subtracted
                                  ;from calibrated data after despin
```

3) For voltage variables, for each value v1 through v6, the offset is subtracted from raw data, then the result is multiplied by the gain factor.

4) For field data, a number of extra steps are needed. First the header information is accessed to determine AC or DC coupling. If both AC and DC coupled modes are present (only possible with efw (wave burst) data), then the appropriate gain is used to convert the raw ADC value.

The offsets input from the calibration files are not used for the spin-plane field components in the default case. Instead, offset values are calculated from the raw data smoothed over a number of spacecraft spin periods (20 by default, but due to the presence of data gaps, may be as short as one spin period). This option may be turned off using keywords, which are summarized below.

Once the offsets are found, the raw data is adjusted for gain and offset. For each field component:

cal_data = -1000*gain*(raw_data - offset)/(boom_length*boom_shorting_factor).

5) The data is now in physically meaningful units of mV/m, but is in a coordinate system spinning with the spacecraft (SPG, space probe geometric coordinates). The default is to return the calibrated data in DSL (despun spacecraft) coordinates. This is done in the program THM_EFI_DESPIN.

The despin procedure is slightly different from a typical THEMIS coordinate change in that the dsc_offset parameter is subtracted from the field after despinning. Thus, if a user simply loads calibrated data in SPG coordinates and then despins using THM_COTRANS, the result will be different from data which are despun in the calibration procedure.

6) Once despun, the _0 and _dot0 fields are calculated. The _0 variables are simply the DSL fields with the spin-axis component (the Z component) set to zero. The _dot0 variables are more complicated. FGM data (by default FGL-low time resolution for EFF and FGH- high time resolution for EFP and EFW), interpolated to the appropriate EFI time array are used for the local magnetic field. For the _dot0 variables, the Z component is a linear combination of the X and Y components calculated so that E dot B is zero (E is perpendicular to the local magnetic field).

7) If the user has requested output in coordinate systems other than SPG or DSL, then coordinate transforms are performed as the final step.

3.0 List of keyword parameters for THM_CAL_EFI:

VERBOSE: Input, >= 1. Set to enable diagnostic message output. Higher values of produce more and lower-level diagnostic messages.

DATATYPE: Input, string. Default setting is to calibrate all raw quantities and also produce all _0 and _dot0 quantities. Use DATATYPE kw to narrow the data products. Wildcards and glob-style patterns accepted (e.g., ef?, *_dot0)

PROBE: Input, string. Specify space-separated probe letters, string array (e.g., 'a c', ['a', 'c']). Defaults to all probes.

VALID_NAMES: Output, string. Return valid datatypes, print them, and return.

COORD: I/O, string. Set to coordinate system of output (e.g., 'gse', 'spg', etc,... see THEMIS Sci. Data Anal. Software Users Guide). Defaults to 'dsl'.

IN_SUFFIX: Input, scalar or array string. Suffix to expect when parsing input TPLOT variable names.

OUT_SUFFIX: I/O, scalar or array string. Suffix to append to output TPLOT variable names in place of IN_SUFFIX (usually = IN_SUFFIX).

TEST: 1 or 0. Disables selected /CONTINUE to MESSAGE. For QA testing only.

STORED_TNAMES: OUTPUT, string array. Returns each TPLOT variable name invoked in a STORE_DATA operation (chron. order). (Not sorted or unique.)

ONTHEFLY_EDC_OFFSET:OUTPUT, float. Return the EDC offset array calculated on-the-fly in a structure (tag name = probe letter, subtagname = datatype). *** WARNING: This kw can use a lot of memory, if processing many datatypes, or long time periods. ***

NO_EDC_OFFSET: I/O, 0 or 1. If set, do not perform an EDC offset calculation. Will also avoid dot0 and_0 calculations, and not perform coordinate transforms. For testing.

GAP_TRIGGER_VALUE: I/O, float, > 0. For on-the-fly EDC offset calculation, consider anything greater than or equal to GAP_TRIGGER_VALUE to be a gap in the data. Default: 0.5 s.

NOMINAL_N_SPINS: I/O, long, >= 1. Specify the number of spins for the on-the-fly EDC offset calculation estimation window, or read out the default (20 spins).

MIN_N_SPINS: I/O, long, 1 <= MIN_N_SPINS <= NOMINAL_N_SPINS. Specifies the lower limit for NOMINAL_N_SPINS.

OFFSET_ESTIMATION_FUNC: OUTPUT, scalar string. The name of the function used to estimate the EDC offset for the on-the-fly window.

EDGE_TRUNCATE: I/O, numeric, 0 or 1. Set to 0 to disable edge truncation in SMOOTH (for the on-the-fly offset calculation). Assign to a variable to read the default (= 1). Undefined, if on-the-fly offset not done.

GAP_BEGIN, GAP_END: OUTPUT, double, >= 0. Return (if they exist), the double-precision start and end times of all gaps detected in preparation for on-the-fly offset calculation. See kw ONTHEFLY_EDC_OFFSET for structure format and warnings.

keyword parameters for _dot0 computation:

MAX_ANGLE: Input, float. Maximum angle of B field to spin axis to calculate _dot0. Typical = 80 degrees. No default.

MIN_BZ: I/O, float. Minimum value of Bz. Typical value is 2.0 nT. Default= 1.0 nT. If argument not defined, returns default. Not compatible with MAX_ANGLE keyword.

MAX_BXY_BZ: Input, float. Maximum value of abs(bx/bz) or abs(by/bz). Typical value is 5. ~= tan(79 degrees) (think of Bx/Bz). Default is not to use this method (no default value).

BZ_OFFSET: I/O, float. Offset in nT that will be added to Z axis measurement of B. Defaults to 0.0. If argument not defined, returns default.

FGM_DATATYPE: Input, string. 'fgl', 'fgh', 'fgs' or 'fge'. The default is to use fgl for eff data, and fgh for the other variables.

FGM_LEVEL: Input, 'l1' or 'l2', default is 'l1'