

## ANODE\_LOOK\_ELC\_DEFL\_EQNS\_V01

This document provides equations to calculate the High Rate Science (HRS) elevations angles for JADE-E when the deflectors are utilized : version 01. This is a simplified version of what the onboard software does. Later versions may improve this to be closer to the onboard software.

The first part is a description of the process, the second part is the IDL code used to represent the process (as used in the JADE product code for this version), albeit it with some cosmetic differences to look better on a page and not wrap lines, e.g.

```
in_file.MAG_VECTOR[* , 0]^2 instead of  
in_file.MAG_VECTOR[* , 0]*in_file.MAG_VECTOR[* , 0]).
```

The electron deflection equations only affect elevation angles of the field-of-view (FOV). For azimuthal angles (with or without deflection) see the relevant version of file ANODE\_LOOK\_ELC\_DEFL\_NONE\_Vnn. To know which version (for either elevation or azimuth) was used for a given Level 3 JADE record, look at the SOURCE\_JADE\_CALIB object which is a version number, *mmmmm*, which corresponds to the file JAD\_L30\_CALIB\_LIST\_*mmmmm*.TXT. This file then says which versions of other files (such as file ANODE\_LOOK\_ELC\_DEFL\_NONE\_Vnn or ANODE\_LOOK\_ELC\_DEFL\_EQNS\_Vnn) were used.

Note: Electron deflectors for HRS were not used for science data during Cruise, nor JOI, their first science use was at Perijove 1 (although they had previously been used during operations check-out tests, but those are not for science use). Any HRS before that time (or if the JADE Level 2 data record has MAG\_VECTOR = [0, 0, 0]) did not deflect, and the non-deflection elevation angles should be used, which are found in the relevant version of file ANODE\_LOOK\_ELC\_DEFL\_NONE\_Vnn (see JAD\_L30\_CALIB\_LIST\_*mmmmm*.TXT for which *nn*).

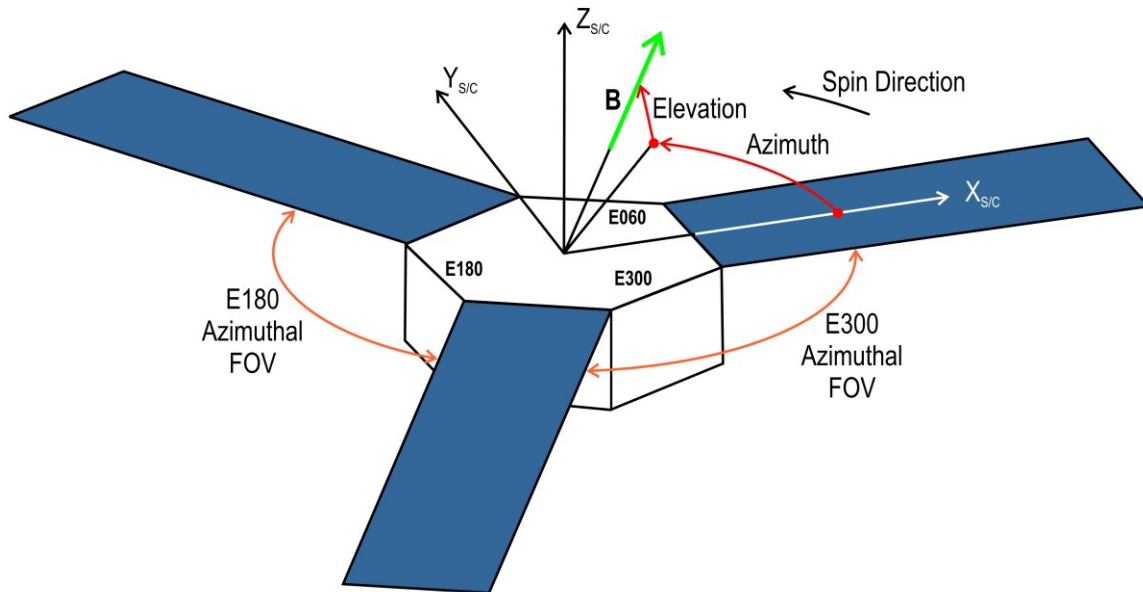
## Deflection Description

The following description is mostly a *cut & paste* from internal JADE document “from\_B\_to\_elevation\_20161020.doc”. The “Broadcast magnetic field” is in spacecraft co-ordinates, and is uncalibrated. It does not list the FWHM of Elevation angle for a given deflection, which is given in separate internal JADE documentation (“JADE-E\_calibration\_report\_v1.docx”) and is based on ground calibration data and electro-optics simulations; relevant parts are also *cut & pasted* here.

## JADE-E elevation of look direction in HRS *Frédéric Allegrini, Sept. 1, 2016*

At the beginning of every energy sweep, JADE uses the propagated broadcast magnetic field to determine the elevation of the look direction and which sensor uses its deflectors:

Broadcast magnetic field:  $B = (B_x, B_y, B_z)$  (1)



Step 0: determine the sign of the deflection angle (positive or negative) for each sensor.

At the beginning of the sweep (every second), the propagated broadcast magnetic field falls onto an anode (called the “mag\_anode”, integer between 0 and 47): if  $J$  is the structure containing the HRS data, then

$\text{mag\_anode} = J.\text{MAG\_LOOK\_DIR}$  (2)

Step 1: calculate elevation,  $\delta$ , in degrees of B in S/C coordinates

$$\delta_B = \arctan\left(\frac{B_z}{\sqrt{B_x^2 + B_y^2}}\right) \quad (3)$$

$|\delta_B|$  is capped at  $35^\circ$ .

If  $\delta_B > 35^\circ$ , then  $\delta_B = 35^\circ$

If  $\delta_B < -35^\circ$ , then  $\delta_B = -35^\circ$

To determine the targeted elevation (i.e., the angle that JADE-E is deflecting to),  $\delta_D$ , for this second we use the following:

- For E060: if  $20 \leq \text{mag\_anode} \leq 43$ , then  $\delta_D = -\delta_B$ , else  $\delta_D = \delta_B$
- For E180: if  $12 \leq \text{mag\_anode} \leq 35$ , then  $\delta_D = \delta_B$ , else  $\delta_D = -\delta_B$

$\delta_D$  is the angle to use for now in the conversion of L2 to L3 JADE-E data. It is the same for all anodes and energies for a given second.

This shortened elevation calculation does not account for offsets from the different conversions within the instrument, errors due to HVPS not reaching targeted voltages, and magnetic field effects on the trajectories.

The steps from the previous version of this document (which took some of the offsets from conversions into account) and refinements to the method will be implemented later as needed.

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The FWHM of Elevation angle is explained on the next page.

Equation 15 of “JADE-E\_calibration\_report\_v1.docx” provides the elevation ( $el$ ) resolution equations as shown below (units of degrees), and their Figure 24 (used as the source of the equations) is pasted below that:

$$el \text{ FWHM} = \begin{cases} 29.9 + 0.758el & -35^\circ \leq el < -32.2^\circ \\ 3.55 - 0.0606el & -32.2^\circ \leq el < 23.4^\circ \\ -0.189 + 0.0993el & 23.4^\circ \leq el \leq 35^\circ \end{cases}$$

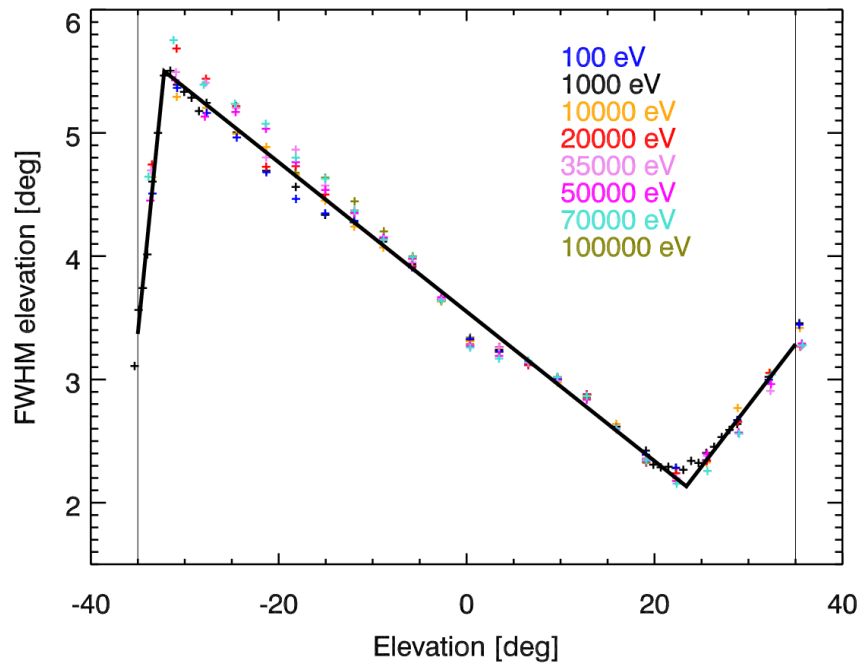


Figure 24. FWHM of the elevation angle distribution as a function of elevation angle from simulations at energies from 102 to 105 eV. The thick lines are fits using Eq. 15.

These equations are used in IDL for the `DIM2_ELEVATION_UPPER` and `DIM2_ELEVATION_LOWER` objects of JADE Level 3 files.

## IDL code used to populate JADE Level 3 files

The code below was used to calculation the center elevation angles (DIM2\_ELEVATION) only if there was deflection.

In\_file is a structure of the objects, which includes fields of:

- **MAG\_VECTOR:**  
A vector (size 3) of the magnetic field in spacecraft co-ordinates (JADE despun spacecraft or regular spacecraft, does not matter, as identical +z axis)
- **MAG\_LOOK\_DIR:**  
Mag\_look\_dir = MAG Look direction (0 to 47) from JADE-E HRS Level 2 files

Specific IDL coding methods:

- IDL uses \$ to continue on next line.
- Doubles are denoted with a d, e.g. 35d = double(35).
- Signed long integers (4-bytes) are denoted with an L (e.g. -1L = long(-1)).
- Numbers without a d or an L are signed short integers (2-bytes).
- EQ = equal, NE = not equal.
- GT = greater than, GE = greater than or equal.
- LT = less than, LE = less than or equal.

```
; If HRS_ALL data was used, the E300 ones will be 65535 so not altered.
Elevation_delta = hrs_electron_deflection_simple(L3,L2.MAG_LOOK_DIR)
; returns -1 if too early for deflection, i.e. cruise

; Preallocate the three elevation arrays with fill values of double(65535)
L3.DIM2_ELEVATION = Elevation_delta ; just to get array of correct size
L3.DIM2_ELEVATION[*] = 65535d ; set all to fill
L3.DIM2_ELEVATION_UPPER = L3.DIM2_ELEVATION ; copy
L3.DIM2_ELEVATION_LOWER = L3.DIM2_ELEVATION ; copy

IF Elevation_delta[0] NE -1 THEN BEGIN
  ind = WHERE(Elevation_delta LT 65534d,/NULL)
  ; using 65534 to avoid rounding issues, expect values < 35, so very safe

  IF N_ELEMENTS(ind) GT 0 THEN BEGIN
    ; First do center values:
    L3.DIM2_ELEVATION[ind] = Elevation_delta[ind]

    ; Work out Delta's, first assume all is in the middle range,
    ; then do the two end ranges, if any.
    Elevation_delta_FWHM = 3.55d - 0.0606d * Elevation_delta

    ind1 = WHERE( Elevation_delta LT -32.2d,/NULL)
    IF (N_ELEMENTS(ind1) GT 0) THEN $
      Elevation_delta_FWHM[ind1] = 29.9d + 0.758d * Elevation_delta[ind1]

    ind1 = WHERE( (Elevation_delta GE 23.4d) AND (Elevation_delta LT 65534d), /NULL)
      ; need to ignore fill values
    IF (N_ELEMENTS(ind1) GT 0) THEN $
      Elevation_delta_FWHM[ind1] = -0.189d +0.0993d * Elevation_delta[ind1]

    ; Divide by 2 to get half FWHM for upper and lower
    Elevation_delta_FWHM = Elevation_delta_FWHM / 2d
    ; base the delta's off the new center energy
    L3.DIM2_ELEVATION_UPPER[ind] = L3.DIM2_ELEVATION[ind] + Elevation_delta_FWHM[ind]
    L3.DIM2_ELEVATION_LOWER[ind] = L3.DIM2_ELEVATION[ind] - Elevation_delta_FWHM[ind]
  ENDIF
ENDIF
```

The function hrs\_electron\_deflection\_simple is given on the next page.

ANODE\_LOOK\_ELC\_DEFL\_EQNS\_V01

```

FUNCTION _hrs_electron_deflection_simple, in_file, Mag_look_dir

; IDL compilation bits - not important
COMPILE_OPT HIDDEN
ON_ERROR, 2 ; Quit if MESSAGE runs

; Check input structure in_file is that of HRS data (PACKETID = 142)
IF in_file.PACKETID[0] NE 142 THEN $
    MESSAGE, 'ERROR: _hrs_electron_deflection only applies to HRS Electron datasets'

; IF DATE BEFORE JOI THEN RETURN, DEFLECTION WAS NEVER ON
; First HRS electron data with deflectors was 2016-240 (2016-Aug-27)
IF in_file.TIMESTAMP_WHOLE[0] LT 520862570 THEN BEGIN ; 520862570 = 2016-Jul-04, JOI
    PRINT, 'Time stamp before JOI, was no HRS deflection to be done. Returning as is.'
    RETURN, -1 ; Use non-deflection Electron values.
ENDIF

; IF AFTER JOI, ONLY E060 and E180 where on, never E300

; pre-allocate array of fill values (65535) for elevation delta
Elevation_delta = in_file.DIM2_ELEVATION ; get right size, be it 32 or 48 anodes
Elevation_delta[*] = 65535d ; make all fill, 65535 as a double (the d)

; Step 0 ; mag_anode must be 0-47 only - enforced before generation of Level 2 files!
mag_anode = ROUND( Mag_look_dir ) ; Round to integer (avoid rounding errors on doubles)

; Step 1, find elevation in degrees and cap at +/- 35 degs
rads2degs = 180d!/DPI ; = 180/pi
deltaB = rads2degs * ATAN( in_file.MAG_VECTOR[*],2) / $
    SQRT( in_file.MAG_VECTOR[*],0)^2 + in_file.MAG_VECTOR[*],1^2 ) ) ; in degrees
deltaB( WHERE( deltaB GT 35d , /NULL ) ) = 35d ; upper cap
deltaB( WHERE( deltaB LT -35d , /NULL ) ) = -35d ; lower cap

; Step 2 - assign elevation based on anode and mag_look_dir
; Do For loop through array as MAG vector can change
FOR rec = 0L, (N_ELEMENTS(in_file.T) - 1L) DO BEGIN
    ; ignore if MAG vector is all zeros or fills (leave Elevation_delta as 65535)
    ; Check for all zeros
    IF ((in_file.MAG_VECTOR[rec,0] EQ 0L) AND (in_file.MAG_VECTOR[rec,1] EQ 0L) AND $
        (in_file.MAG_VECTOR[rec,2] EQ 0L)) THEN CONTINUE; skip if no MAG vector ([0,0,0])
    ; Then check for any MAG_VECTOR fill values, 2147483647, but to avoid rounding errors
    ; use 1 less and GT (>), so 2147483647-1 = 2147483646
    IF (in_file.MAG_VECTOR[rec,0] GT 2147483646L) THEN CONTINUE
    IF (in_file.MAG_VECTOR[rec,1] GT 2147483646L) THEN CONTINUE
    IF (in_file.MAG_VECTOR[rec,2] GT 2147483646L) THEN CONTINUE

    ; Still in For Loop - so MAG vector is not zeros nor fill values.

    ; Now do elevation for E060
    IF ((mag_anode[rec] GE 20) AND (mag_anode[rec] LE 43)) THEN BEGIN
        Elevation_delta[rec,*, 0:15] = -deltaB[rec]
    ENDIF ELSE BEGIN
        Elevation_delta[rec,*, 0:15] = deltaB[rec]
    ENDELSE
    ; Now do elevation for E180
    IF ((mag_anode[rec] GE 12) AND (mag_anode[rec] LE 35)) THEN BEGIN
        Elevation_delta[rec,*, 16:31] = deltaB[rec]
    ENDIF ELSE BEGIN
        Elevation_delta[rec,*, 16:31] = -deltaB[rec]
    ENDELSE
    ; Nothing to do for E300, it's all fills - which is already pre-allocated
ENDFOR

RETURN, Elevation_delta
END

```