Automated Pointing Models Using the FS

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May 2019 TOW

1.0 Why we check pointing and SEFDs before each experiment

An initial check of pointing serves to verify that several aspects of the system are working correctly.

1.1 Verify signal is getting from the front-end to the back-end

The very act of checking the pointing and SEFDs using the detectors in the DAR verifies that signal is getting to the back-end. Each channel should yield the expected sensitivity and beamwidth. See also 1.5.

1.2 Verify sensitivity

The SEFD is a very useful measure of the antenna's sensitivity. Verifying that you get the expected sensitivity demonstrates that many parts of the system have not failed since the last more thorough check.

1.3 Verify pointing is good

Verifying that the pointing is good demonstrates that there has been no serious degradation in the antenna's pointing accuracy since it was last checked.

1.4 Verify system time and date

Depending on the details of the antenna interface, checking the pointing verifies that the date and time in either the FS computer or the pointing computer or both are correct at some level. If both, i.e., the FS and pointing computer have independent times, you should verify each independently, and compare them to each other. An error of one day will cause an approximately 1° pointing error. An error of a few seconds may not be detected, unless the beam is small enough.

1.5 Verify IFs aren't switched (many stations don't need this)

If you switch IFs depending on the experiment, verifying the beamwidths and SEFDs of each IF is good check that they are connected to the correct channels.

1.6 Things that can't be checked by pointing and SEFDs

These are some of the items that aren't verified easily by checking the pointing and SEFDs. They require some other means of verification that will typically be different at different stations.

1.6.1 Polarization

The sensitivity of the antenna may not be very different for different polarizations.

1.6.2 Sub-band

If you have more than one IF for a given band it may be difficult to distinguish between them based on the measured beamwidth.

1.6.3 Time errors below the level detectable by the beam

Unless the beam is small you may not be able to detect errors on the order of one second in time, much less a fraction of a second.

2.0 Set-up

There are several steps that are needed to set-up pointing checks in the FS. They need to be done only once. After that, the steps in the following sections can be expected to work. Please see the ACP User Guide manual, Section 5, in Vol.2 of the FS Manuals for more information on installing the system.

2.1 `antcn` must support modes 0-5 (plus 8 for non-standard detectors)

`antcn` provides the basic interface between the FS and the antenna. The listed modes must be supported for the `fivpt` and `onoff` programs to work. Please refer to the FS Manuals Vol. 2, Station Programs manual or the TOW seminar "Topics in FS Coding" for more information on implementing `antcn`.

2.2 Set-up the `.rxg` files.

The `.rxg` files contain the gain calibration information for each band. It contains: LO values (or range if tunable), polarizations available, FWHM, the gain curve, gain values (DPFU) for each polarization, and Tcal values as a function of frequency for each polarization. The set-up of these files is described in the default files in `/usr2/fs/st.default/control/rxg_files` (`x.rxg` and `s.rxg`). Don't change the versions in the `/usr2/fs` source tree (the FS doesn't use those copies). Instead, copy/rename the default files to the `/usr2/control/rxg_files` directory giving them names (the part before the

`.rxg`) that are mnemonic for the band or receiver, and edit them there. There are no fixed values for the names, but they must be unique within the directory. The FS will read in all files with the extension `.rxg`, up to 20 of them. The comments in the default files should be self explanatory, but here are a few hints about how to set-up the files. The lines you should probably edit are:

(1) The LO values, this must match the values used in the `LO=...` command for the RX you will be using. PLEASE NOTE: you should not put information for a given LO value (even within a range) in more than one file, i.e., any given LO value should not be covered by more than one `.rxg` file.

(2) Creation date.

(3) The FWHM of the beam.

(4) The polarizations available: `lcp` and/or `rcp` (currently for horizontal and vertical use `lcp` and `rcp` respective, they can be related by the mnemonic that both are in alphabetical order: “l” then “r”, “h” then “v”).

(5) The DPFU(s). If you don’t know them, they can be estimated as the Tsys in Kelvin divided by the SEFD.

(6) Gain curve. If you have a gain curve in the form of `ELEV POLY` or `ALTAZ POLY`, you can enter the coefficients on the appropriate line, zeroth order term first, if you have no gain curve leave the value as `1.0`.

(7 and the following lines up to `end_tcal_table` line) Tcal versus frequency table. If you have this information, currently there can be up to 1200 total lines (as of FS 9.13.0), if you don’t have this information you can enter a single value for each polarization in the band and the FS will use that for all frequencies.

(the line after the `end_tcal_table` line) Receiver noise temperatures. Values of zero will do for an initial guess.

(the remaining lines up to the `end_spillover_table` line) A spillover table. Currently up to 20 lines, a spillover table is not needed initially but can be entered if available.

2.3 Customize `ctlpo.ctl`

This control file specifies the sources that `aquir` will attempt to observe and what actions it will take for each. Typically, the only changes needed are to decide which sources are suitable for pointing and SEFD measurements at the band being used. Sources can be repeated for additional/different measurements on them. Unused sources can be commented out. You can of course have multiple version of this file for different bands and applications. Different versions of this file might also refer to different versions, if needed, of the `initp` procedure in the `point` procedure library.

2.4 Customize `point.prc`

This procedure library contains the pointing specific SNAP procedures that are needed by the `aquir` program and/or are otherwise general useful for pointing checks, especially with a dual S/X receiver. You can of course have multiple version of this file for different bands and applications. Another alternative is to have differently named procedures for different bands and applications.

2.4.1 The `initp` procedure should completely set-up system.

This procedure is used to initialize the system before doing any pointing or SEFD. It should fully set-up any equipment that is needed, including any station specific equipment. It should also do any necessary software set-up such as the parameters to sue for the `fivept` and `onoff` commands. You can have different version for different bands and/or different purposes, e.g., pointing versus gain calibration,

2.4.2 The `acquire` procedure to initiate acquisition

This procedure can set the log to convenient name for the purpose of the acquisition (the default is `point)` and run the `aquir` program with the appropriate version of `ctlpo.ctl`. The `aquir` program accepts a single argument, which is the name of the source (as stored in the control file) to start measurements with, if it is up. If no source is specified it starts with the first one that is up.

2.4.3 The `prep` procedure

This procedure is used to do any per source initialization. This can include setting initial offsets, if the current model is too far, adjusting gain, and sampling meteorological data, as well as other actions. You can specify different versions on each source. This also might be useful to select different BBC frequencies for the measurements for multiple instances of the same source to cover more frequency range more densely.

2.5 Customize `parpo.ctl`

This file is used to control the editing of pointing data during the initial extraction of the data from the log. Generally, you should just enter your antenna name and its axis type and turn off the editing features which as mostly obsolete. It is recommended that the hex control flag on line 3 have the value `3`.

2.6 Customize `mdlpo.ctl`

This file contains the standard FS pointing model. It is used by the pointing data analysis programs. If your `antcn` uses it also to calculate pointing corrections, the results of a pointing analysis are directly available to correct the pointing of your antenna. The angle of the fixed axis relative the ground, φ (phi) must be entered in degrees: AZ/EL uses `90`, X/Y antennas `0` and HA/DC antennas use the geodetic latitude. Normally, the first eight parameters are turned on initially. However, it is recommended that the second parameter be turned off if φ is `90`, i.e., usually for AZ/EL antennas. Additionally, parameters may be needed if there are other unmodeled systematics in the results when they are analyzed. Normally, the parameter values are initially zero.

2.7 `flux.ctl`

This file contains the source flux models. It should not need to be customized unless there are sources that you use that aren't included. If so, please send them to Ed (Ed.Himwich@nasa.gov) to be added to the default version.

2.8 What if you have a non-standard detector

If you have a non-standard detector, e.g., a power meter, you can support it using mode 8 of `antcn`. Two non-standard detectors, `u5` and `u6` are supported. The implementation assumes you have some way to remove the signal from the detectors under computer control, e.g., by switching a large value of attenuation into the signal path. This is done by the standard procedure `sigoff`. The normal attenuation is restored by the standard `sigon` procedure. These procedures are also discussed in the help pages for `fivept` and `onoff`. Please see the file `/usr2/fs/misc/stndet.txt` for details on how to implement the detector in `antcn` mode `8`. Please note that the "Use" section in the version of this document from before FS version 9.9.3 is out of date. If you don't have FS 9.9.3 or later, you can obtain a more up to date version of the file from Ed (Ed.Himwich@nasa.gov). Please see the help file for the `user_device` SNAP command for how to define the parameters for the user devices. As of FS 9.13.1, you can disable the use of `sigon` and `sigoff` if the zero level of your detector is close enough to zero; this is often the case for digital detectors.

2.9 What if you have no cal diode

If you have no noise diode, set the diode noise temperatures in the relevant `.rxg` file to a negative value. The absolute value of the specified noise temperatures will be assumed by the pointing programs to be the system temperature. The antenna temperature due to the source will be calculated on this assumption. However, the SEFDs will be unaffected. A value of -100 is convenient. The result will be that antenna temperatures will come out in percent of the system temperature (which may vary, for example with elevation).

3.0 Manual checks

This section describes how to perform manual checks once the system has been set-up as described in the previous section. This is described in more detail in ACP User Guide manual, Section 3, in Vol.2 of the FS Manuals. Start the FS and enter the following commands in order:

3.1 `proc=point`

This command selects the `point.prc` SNAP library. If you are using a pointing library with a different name, such as `vpoint.prc`, enter that library's name instead

3.2 `initp`

This command runs the `initp` procedure, which should have been customized already to set-up your equipment for pointing checks.

3.3 (*`source procedure`*)

Here you enter the name of the source that you want to use to check pointing. The procedure library `point.prc` has procedures with coordinates for most of the useful Northern Hemisphere pointing sources. To see which are available, use the `ds` command in `pfmed`, when `point` is the selected library. The flux models for the sources that are good calibrators are include in the `flux.ctl` file.

3.4 `prep`

This command runs the pre-source initialization, which may be needed for example to adjust the gain.

3.5 `fivept`

This command runs the `fivpt` program to peak on a source. It does this by measuring the power level on two slices through the source. Normally you would wait for the source to be acquired before typing this command, but if the antenna isn't onsource and `aquir` isn't running, `fivpt` will wait for up to one minute for onsource to be achieved before giving up. When `fivpt` finishes normally it logs an `offset` record. If some very nominal checks of whether this was a good peak are passed, the `offset` record will have two ones (`1 1`) at the end signifying success. The first four parameters in the `offset` record are: (1) first axis coordinate, (2) second axis coordinate, (3) first axis offset, and (4) second axis offset. The `xoffset` record contains similar information, but reports the first axis offset corrected for cosine of the second axis coordinate (the so-called "cross" offset) and the sigmas of the offsets (first axis sigma also corrected for the elevation). The values in the `xoffset` record are generally more useful than the `offset` record for a quick determination of whether the pointing is good and include the detector and source names to facilitate selection with `grep`.

3.6 `onoff`

This command runs the `onoff` program to measure SEFDs and other antenna performance parameters. If you execute it immediately after `fivpt` has finished, leaving in the offsets that `fivpt` found, you will get a "peak" performance measurement.

3.7 (*`next source procedure`*)

If you wish to make another measurement, select a new source. If the `fivpt` program for some reason returned unrealistic offsets, you may want to remove them before trying to peak on the next source. Continue using `prep`, `fivept`, and `onoff` for each additional source as desired. See the sectioned "**3.8** When finished" (below) for how to remove the offsets.

3.8 When finished

If you do not want the most recent `fivpt` offsets to remain in use (typically for geodesy observing you don't), use `xyoff=0d,0d`, `azeloff=0d,0d`, or `radecoff=0s,0d` (or whatever offsets are desired) depending on the axis system of your antenna.

4.0 What `fivpt` does

This section briefly describes what `fivpt` does.

4.1 Measure Tsys off source to calibrate scale

This is the first step. It uses the noise diode to measure the system temperature off source. If there is no noise diode, indicated by noise diode temperature less than zero, then the negative of the specified diode temperature is assumed to be the temperature of the system off source in order to calculate the necessary conversion factors.

4.2 Scan both axes

The source is scanned on two axes, nominally aligned with the telescopes natural coordinates. Typically, nine measurements, 0.4 FWHM beamwidths apart, are taken.

The data are displayed in the `lat` and `lon` records. These correspond respectively to the latitude-like and longitude-like coordinates of the antenna: EL/AZ, Y/X, and DEC/HA, respectively. The data in each record are: (1) the number of the point, (2) the seconds since the midnight previous to the scan (which grows monotonically even if a scan spans another midnight), (3) the offset on the scanned axis, (4) the antenna temperature due to the source (above the measure system temperature, may be negative due to changes in ground pick-up and RFI), and (5) if the integration period is larger than one, the RMS scatter of the samples.

4.3 Fit Gaussian + offset + slope

The data for each axis are fit to a five-parameter function consisting of a Gaussian (three parameters: peak offset, half-power beamwidth, and peak temperature) plus an offset and slope (in time). If the fit is nominally successful, the last parameter on the *XXX*`fit` (*XXX* is `lat` or `lon`) line is positive. The estimated errors in the parameters are displayed in the associated *XXX*`err` line; the last value of which is the RMS fit of the model to the data.

4.4 Repeat if not well centered or a fit failed

For a typical set-up, if the peak for either axis is off by more than a half measurement step (this is perhaps too tight) or if the fit on either axis failed, the measurement will be repeated a second time. This assures that the source is roughly centered in the data set, which may also be helpful in the case of a weak source. For weak sources, if the beam is not well centered on the second axis scanned, the first axis scanned may not have enough signal from the source to find a clear peak.

4.5 Leave the telescope “peaked” on source

After the final scan, the offsets of the fitted peak are left in use. This is useful if you plan to run `onoff` next to find the “peak” performance. However, be careful after doing pointing checks to remove the last offsets before acquiring VLBI data, unless the source is strong and you will be acquiring data on that source in that part of the sky only (this is not usually the case for geodesy).

4.6 Sample `fivpt` output

The following is an example `fivpt` output. The format of the time/date stamp in the log is an old form no longer in use now, but the actual entries are current.

```
9735612401440#fivpt#source cas-a      232109.0 +583230 1950.0 97/356.12:40:14
9735612401445#fivpt#site GILCREEK 147.4976  64.9784   0.00 xxxx   0  1.00  0.00
9735612401445#fivpt#fivept xyns  -2  9 0.40  1 3u  19.0  0.0834     399.1
9735612401451#fivpt#origin   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
9735612402363;calofffp
9735612402806;calonfp
9735612403043;calofffp
9735612403066#fivpt#tsys 336.447  36.913  61.922
9735612404069#fivpt#lat   1  45640.  -0.1334    1.158
9735612404894#fivpt#lat   2  45648.  -0.1001    2.183
9735612405769#fivpt#lat   3  45657.  -0.0667   11.597
9735612410669#fivpt#lat   4  45666.  -0.0334   29.098
9735612411569#fivpt#lat   5  45675.   0.0000   38.361
9735612412469#fivpt#lat   6  45684.   0.0334   28.832
9735612413369#fivpt#lat   7  45693.   0.0667   11.370
9735612414269#fivpt#lat   8  45702.   0.1001    2.556
9735612415094#fivpt#lat   9  45710.   0.1334    1.227
9735612415095#fivpt#latfit  -0.00032  0.0994 38.3030  0.5406  0.0035   4
9735612415095#fivpt#laterr   0.00070  0.0020  0.5503  0.3844  0.0098   0.5838
9735612415968#fivpt#lon   1  45719.  -0.1971    1.177
9735612420869#fivpt#lon   2  45728.  -0.1479    3.239
9735612421694#fivpt#lon   3  45736.  -0.0986   12.508
9735612422569#fivpt#lon   4  45745.  -0.0493   29.294
9735612423394#fivpt#lon   5  45753.   0.0000   39.025
9735612424269#fivpt#lon   6  45762.   0.0493   30.376
9735612425169#fivpt#lon   7  45771.   0.0986   12.768
9735612425994#fivpt#lon   8  45779.   0.1479    2.594
9735612430869#fivpt#lon   9  45788.   0.1971    1.531
9735612430870#fivpt#lonfit   0.00110  0.1024 38.7746  0.6563 -0.0033   5
9735612430870#fivpt#lonerr   0.00111  0.0022  0.5846  0.4250  0.0108   0.6198
9735612430870#fivpt#perform    2.041   637.4    0.509    8.223
9735612431562#fivpt#offset   332.6681   47.5413   0.00110  -0.00032  1  1
9735612431562#fivpt#xoffset  332.6681   47.5413   0.00074  -0.00032  0.00075  0.00070 1 1 cas-a
```

(The `xoffset` record in this example was manufactured by hand for illustration purposes. This was necessary because the example shown data was collected before this feature existed.)

5.0 What `onoff` does

The `onoff` program is a simple tool for measuring the SEFDs of the antenna in multiple detector channels simultaneously.

The following measurements are made, typically with two iterations for everything except the no signal case, which is only collected in the first iteration the actual displayed log record labels shown in square brackets ([…]):

- **5.1.1** Power on source [`ONSO`]
- **5.1.2** Power on source with noise diode on [`ONSC`]
- **5.1.3** Power off source with noise diode on [`OFFC`]
- **5.1.4** Power off source with noise diode off [`OFFS`]
- **5.1.5** Power off source with no signal for "zero" level [`ZERO`]

A final set of power onsource and onsource with noise diode on are included to make the on and off source measurement procedure symmetric in time.

5.2 Final results are displayed on one like for each detector: Gain Compression, Tsys, SEFD, Tcal(j) in Janskys, Tcal(r) ratio. For interpretation of the last two items, please see the notes for the TOW **Antenna Gain Calibration** and **Pointing and Single Dish Amplitude Calibration** classes.

The results are printed in several forms to facilitate analysis depending on what is needed. You need to be careful of Tsys and Tcal(r) ratio values which depend on the accuracy of the *a priori* noise diode values. The Compression, SEFD, and Tcal(j) in Janskys do not depend on the *a priori* noise diode values.

5.3 Sample final results from `onoff` output

```
2002.310.20:49:31.27#onoff#    source       Az   El   De I P   Center   Comp   Tsys  SEFD  Tcal(j) Tcal(r)
2002.310.20:49:31.28#onoff#VAL cygnusa    273.4 52.0 1u 1 l   4969.99 0.2658 18.34  438.0 487.272 2.8850
2002.310.20:49:31.28#onoff#VAL cygnusa    273.4 52.0 2u 2 r   4969.99 0.2548 16.83  421.3 480.612 3.0234
2002.310.20:49:31.28#onoff#VAL cygnusa    273.4 52.0 3u 1 l   4977.99 0.2869 17.70  435.2 501.462 2.9690
2002.310.20:49:31.28#onoff#VAL cygnusa    273.4 52.0 4u 2 r   4977.99 0.2673 16.78  425.8 487.400 3.0661
2002.310.20:49:31.28#onoff#VAL cygnusa    273.4 52.0 5u 1 l   4985.99 0.3214 17.25  445.8 527.168 3.1212
2002.310.20:49:31.29#onoff#VAL cygnusa    273.4 52.0 6u 2 r   4985.99 0.3032 15.81  422.6 513.282 3.2289
2002.310.20:49:31.29#onoff#VAL cygnusa    273.4 52.0 7u 1 l   4993.99 0.3533 16.68  452.2 553.065 3.2745
2002.310.20:49:31.29#onoff#VAL cygnusa    273.4 52.0 8u 2 r   4993.99 0.3353 15.39  431.3 537.976 3.3842
2002.310.20:49:31.29#onoff#VAL cygnusa    273.4 52.0 9u 1 l   5001.99 0.3684 16.45  455.1 564.312 3.3411
2002.310.20:49:31.29#onoff#VAL cygnusa    273.4 52.0 au 2 r   5001.99 0.3464 15.14  430.8 546.332 3.4368
2002.310.20:49:31.29#onoff#VAL cygnusa    273.4 52.0 bu 1 l   5009.99 0.3959 15.67  454.0 591.040 3.4993
2002.310.20:49:31.30#onoff#VAL cygnusa    273.4 52.0 cu 2 r   5009.99 0.3710 14.79  437.0 567.122 3.5676
2002.310.20:49:31.30#onoff#VAL cygnusa    273.4 52.0 du 1 l   5017.99 0.4232 15.43  468.8 619.723 3.6691
2002.310.20:49:31.30#onoff#VAL cygnusa    273.4 52.0 eu 2 r   5017.99 0.3912 14.57  444.4 585.618 3.6839
2002.310.20:49:31.30#onoff#    source       Az   El   De I P   Center   Comp   Tsys  SEFD  Tcal(j) Tcal(r)
```

6.0 Automated measurements

This section describes what is needed for automated measurements. Once set-up, this is even easier than doing manual measurements. Start the FS and enter the following commands in order:

6.1 `proc=point`

This command selects the `point.prc` SNAP library. If you are using a pointing library with a different name, such as `vpoint.prc`, enter that library's name instead.

6.2 `acquire`

This procedure starts the `aquir` program running. Typically, `aquir` uses the `ctlpo.ctl` control file and the log is changed to `point.log`. However, you can have other procedures that start acquisition and that use other control files. For example, you could make a version that uses only the very strongest sources for a quick pointing check and returns the offsets to zero when stopped. Once started, `aquir` runs indefinitely until it is `kill`'ed. Typically, you use `acquire=`*`source`* to start with a specific source.

6.3 To stop: `kill`

The `kill` procedure will stop any of `fivpt`, `onoff`, and `aquir` that happen to be running. Typically, it also changes the log back to `station.log`. Using `kill` does not normally change the offsets back to zero. Follow the procedure under "**3.7** When Finished" in the "**3.0** Manual Checks" section above, to do that.

7.0 Pointing Data Analysis: `pdplt`

This section describes the use of the `pdplt` program to analyze pointing data to determine a pointing model. The `pdplt` program is a `Tcl/Tk` application that provides a graphical front-end for the text based pointing data analysis programs. It is run by typing `pdplt` to a shell prompt. A brief sketch of some of its capabilities follows. More information can be found in the `pdplt` documentation available on the FS servers.

7.1 Selecting a New input file

To select the input file, click on the `File` main menu entry and then select `New`. This will display a `Tk` file selection dialogue box open to `/usr2/log`. You can either type the name of the file, including its extension, such as `.log` or navigate using the dialogue box and double click on the file you want. You can load a FS log file even while pointing data is being written to it for a check of the results "so-far".

Please note the model file (usually `mdlpo.ctl`) in `pdplt` must be the same as the one used to collect the data; this is usually the case for this input option. You can change the used model file by changing the `Control file for error` under `I/O Setup` on the `File` menu.

7.2 Selecting an existing input file

Click on the `File` main menu entry. There is an `Open` option that can be used to open an existing `xtrac` output file such as was saved by the `Save` option on this menu.

Please note when choosing this option, you must use the same model file (usually `mdlpo.ctl`) in `pdplt` as was used when the data was collected; this will typically NOT be the case for this input option. Please see section 7.13 for how to change the used model file in `pdplt` if that is needed.

7.3 Examining sky coverage

The first plot that is shown is sky coverage. This is done in the natural coordinates of your antenna assuming that the `parpo.ctl` control file has been set-up correctly. You can select which graph to look at using the `Graph` menu to select which graph to examine. The letters `n` and `p` can be typed to move the next and previous graphs respectively (with wrap around at the ends). See the attached plot of sky coverage for a pointing data set from Tsukuba. Ideally, the entire sky should be covered more or less uniformly. In this case, the sky coverage in this case is remarkably good due to Tsukuba being a very sensitive antenna at a mid-Northern latitude location.

7.4 Points on the plots

Points that are included in the solution are shown as solid circles. Points that are deleted are show as open circles. Information on individual points is displayed when the pointer comes over or near it. On the residual plots all included points are shown by default on the interior of the plots when they have been auto-scaled. Any points that lie outside the range of the plots are shown on the edge. Points are normally shown with one-sigma *a priori* error bars (see section 7.10 for control of how the error bars are displayed).

7.5 Residuals, random versus outliers and non-random

Ideally the residuals of the pointing solution should appear to be a random scatter about zero offset with a Gaussian distribution for both offsets types against both axes (four plots). Two major reasons they might not be are: (1) so-called “blunder” points, which are just points that lie a lot farther from zero than other points in the vicinity, due for example, to some failure of `fivpt`, and (2) systematic trends in the data, such as slope, curve, or sinusoid pattern in the residuals. To correct the former problem, you can remove a point by editing it out of the data, see “Editing Data” below. The latter problem usually has to be dealt with by changing the model, see “Changing the Model Parameters” below.

By default, the residuals to the fit as shown on the plots. There is one attached plot that shows the raw points for Elevation offsets versus azimuth (see section "**7.7** Viewing the raw data") for a data set collected at Tsukuba. Even though these are raw data, except for one thing they would look almost as random as an acceptable set of residuals. The exception is that there is a roughly sinusoidal variation in the offsets as function of azimuth. Another attached plot shows the post-fit residuals for the same data. In this case, there is no visible systematic; an updated pointing model absorbed this effect. (You can tell the two plots apart by the presence or absence of this sinusoidal variation and the added legend at the top.) This is an example of how the fitting process can remove systematic variations from the raw data. The resulting model will point the antenna more accurately than it pointed before the new model.

Another default behavior of `pdplt` is that the offsets for the first (the longitude-like) coordinate (Az, X, or H.A.) are displayed as "cross" offsets, which means they are multiplied by the cosine of the second (the latitude-like) coordinate. This has the effect of normalizing the scatter of points far from the zero point of the second coordinate due to the compression of the first coordinate near the poles of the second. The "cross" offsets are labeled as `xEL`, `xY`, and `xDC` on the plots. This behavior can be turned off, i.e., to display the first coordinate offsets in unmodified form, by adjusting the flag in the third line of the `parpo.ctl` control file. This flag can also be used to independently change the use of "cross" coordinate formal error constants to non-cross formal error constants. The formal error constants are used to adjust the normalized scatter of the residuals to be near unity. However, both display of "cross" offsets and use of "cross" coordinate formal error constants is recommended. In the former case, it makes the residuals for the first axis easier to evaluate visually. In the latter case, it represents unmodeled errors for the first axis as a noise level in the precision of the offset determination rather than the precision of the encoder read-out.

7.6 Viewing individual sources

Individual sources can be highlighted by selecting them from the `Source` menu item. This is useful for identifying which points go with which sources and to see if there is any source specific systematic behavior.

7.7 Viewing the raw data

When testing to see if a new pointing model is needed, it is useful as a first step to examine the raw data. You can select to view the raw data from the `Data` main menu. The choices on the menu are `raw data` and `residuals`. If you select `raw data` the plots and statistics (see next sub-section) will refer to the raw data rather than the default residuals to the latest solution.

7.8 Statistics

The number points used and available are shown in the lower right of the display in the format used/available.

The average and RMS scatter of the residuals (or raw data) for both axes can be shown by selecting the `Statistics` menu item. If the average error for the residuals on either axis isn't zero when the residuals are displayed, something is wrong. e.g., an offset parameter may not be selected for that axis. The average may be non-zero for raw data. The RMS residual scatters for a good solution would typically be 10% or less of the full-width half-maximum power (FWHM) beamwidth.

7.9 Editing data

Strictly speaking data should never be edited. However, in the words of a teacher I once had "real data is nasty stuff". In other words, it has all sorts of "blunders" and errors that make some points simply invalid and distort the results. The problem is that strictly speaking without *a priori* knowledge there is no way to tell for sure which points are blunder points and which are really telling you that there is something wrong with your pointing model form. Fortunately, with pointing data, simple models are usually enough. Editing does however need to be done conservatively to be safe.

7.9.1 Three-Sigma editing

One of the more defensible forms of editing when there are a lot of data is to apply is an "*X*-sigma" criteria, "*X*" is usually "three". In other words, if a residual differs from zero by more than three times its sigma, it should be removed. For well distributed data, typically 1% are removed under a three-sigma criterion. The `Edit` menu item has a `x-sigma` option to apply such a criterion uniformly to all the data on both axes. Afterwards, the data should be reprocessed by selecting the `Reprocess` option on the `Edit` menu item. It may be necessary to iterate the X-sigma editing and reprocessing several times before only a few or (hopefully) no more points are removed. This process will fail if the residuals do not have a Gaussian distribution, because in most such cases the editing will progressively remove more data on each step until there are no data left. If that happens or a significant fraction of the data is removed, you need to investigate why the residuals do not have a Gaussian distribution. If possible this should be corrected, perhaps by changing the model. If it can't be corrected, you will need to stop editing after one or two iterations and hope for the best.

7.9.2 "Point and shoot" manual editing

A somewhat less defensible approach is to manually delete any points with residuals that differ significantly from zero relative to their error bars. This is a somewhat artistic process. It is needed sometimes to remove big outliers either because there aren't enough data to apply a three-sigma criterion or some other reason. Since the plot limits include the extent of error bars on points it is sometimes helpful to delete all points that have unusually large error bars. These points usually do not contribute anything significant to the solution. If their error bars are very large compared to the error bars for the bulk of points it is likely that they are blunder points anyway. However, you have to be careful, for example, if you are viewing azimuth offsets (instead of xEL offsets), points with large error bars at high elevations may be legitimate and significant.

To add or remove a point manually, place the pointer on or near it and click on it. The point selection is slightly "sloppy" because it was found to be hard to use otherwise. You can also adjust the plot axes to make it easier to distinguish points that are close together. After editing out or adding back in points, be sure to reprocess the data using the `Reprocess` option on the `Edit` menu item. There is also an `Add all points` option on the `Edit` menu item to return all points to the solution.

7.10 Sigmas

Three types of sigmas are available for use or display in `pdplt`. The default sigma, the *a priori*, is the most useful and is the only one that is normally needed. (You can stop reading this paragraph at this point and skip to the next sub-section unless you want to know more about this.) This value combines the effect of the raw observed sigma with the added noise for each axis that had to be applied to make the reduced χ^2 of the solution come out close to unity. This provides in some sense the best available estimate of the true sigmas of the input data. The other types are: (1) "input", which is just the raw observation sigma and doesn't include the added noise contribution, this is mostly a curiosity and (2) "*a posteriori*" which is the sigma of the residuals after the solution, rather than of the input data. Ideally the *a posteriori* sigma should be used for all editing operations, but in practice this is a subtle distinction. For pointing data, except in situations with very sparse data, it is usually the same as the *a priori* sigma. If the data are sparse enough that there is a significant difference between the *a priori* and *a posteriori* sigma, then there may not be enough data to make a good solution anyway. Consequently, the *a posteriori* sigma is mostly a curiosity as well, but in some cases it may be useful.

7.10 Printing plots

Plots can be printed individually either directly to the printer or to a file. The output is PostScript. Select the `Print` option from the `File` menu option.

7.11 Saving the results

The results can be saved using the `Save` option from the `File` menu. The data, including any editing, is typically saved to a file with a name of the form `xtr`*`YYYY.DDD`* in `/usr2/log/`, where *`YYYY.DDD`* is the last digits of the year and day of the year. The date is taken from the log the data were extracted from. This file is the format of an `xtrac` program output file and can be read into `pdplt` again using the `Open` option in the `File` menu option. The results of the analysis are saved in a file of `err`*`YYYY.DDD`*. This file is in the format of an `error` program output file. This file is used by in updating model step described below. The options for saving the data can be modified using the `I/O Setup` option from the `File` menu item.

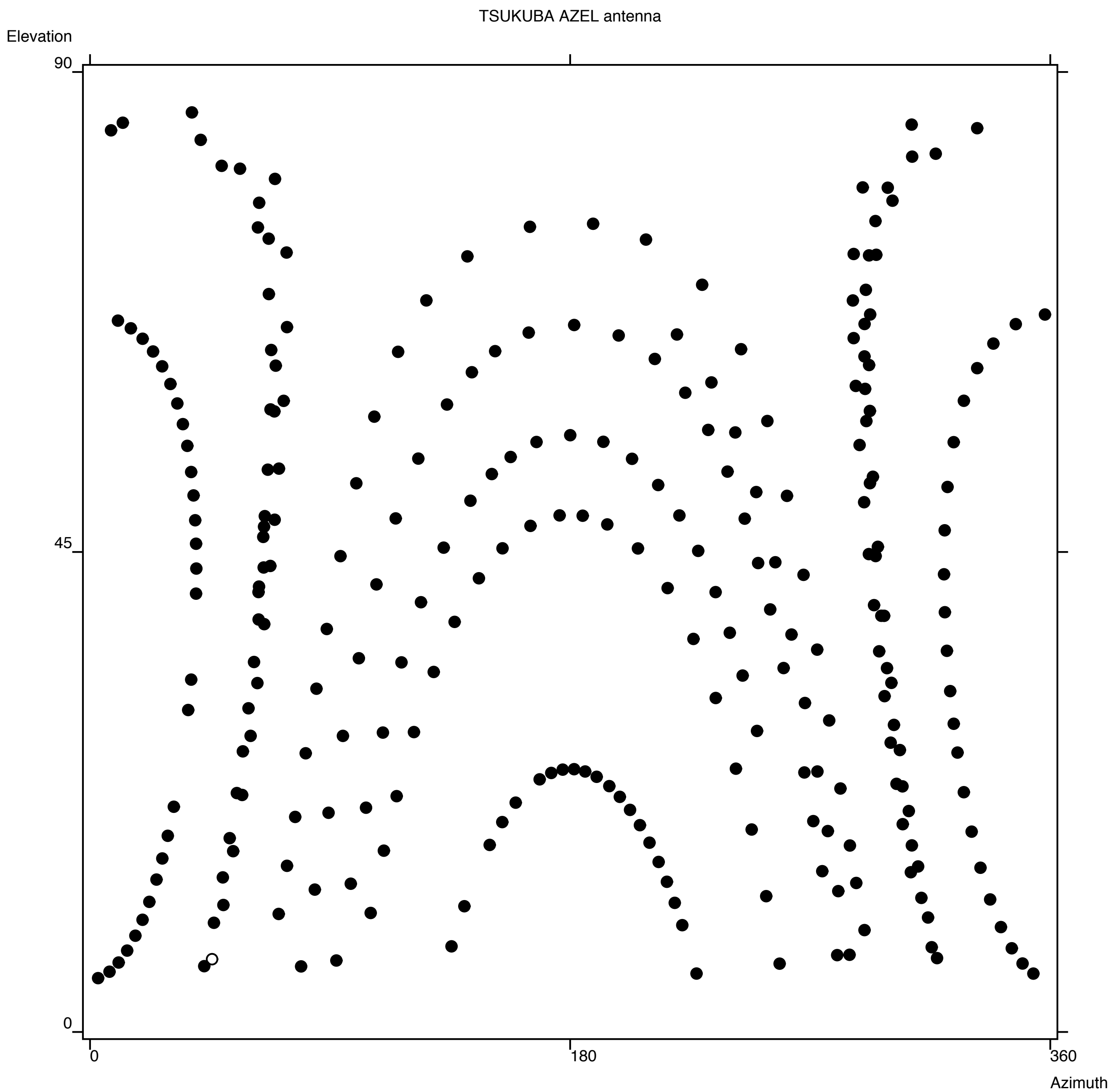
7.12 Update the model with `update` *`YYYY.DDD`* and restart the FS

Once the analysis has been finalized and the results saved as described above, the model can be updated. Issue the command `update` *`YYYY.DDD`* while in a shell, where *`YYYY.DDD`* is suffix of the `err`*`YYYY.DDD`* file created when the results were saved. The suffix doesn't necessarily have to be in the format of *`YYYY.DDD`* as long as it is specified as the argument for `update` and agrees with the actual suffix to `err` in the file name. The `update` program will comment out the active model in `mdlpo.ctl` and append the new one. To begin using the new model, stop the FS and restart it (or do whatever is necessary to have the model read in if your `antcn` doesn't read it automatically at start-up, maybe you need to enter it by hand into your pointing computer). You should always do at least a quick pointing check to make sure that the new model is good before using it for an experiment.

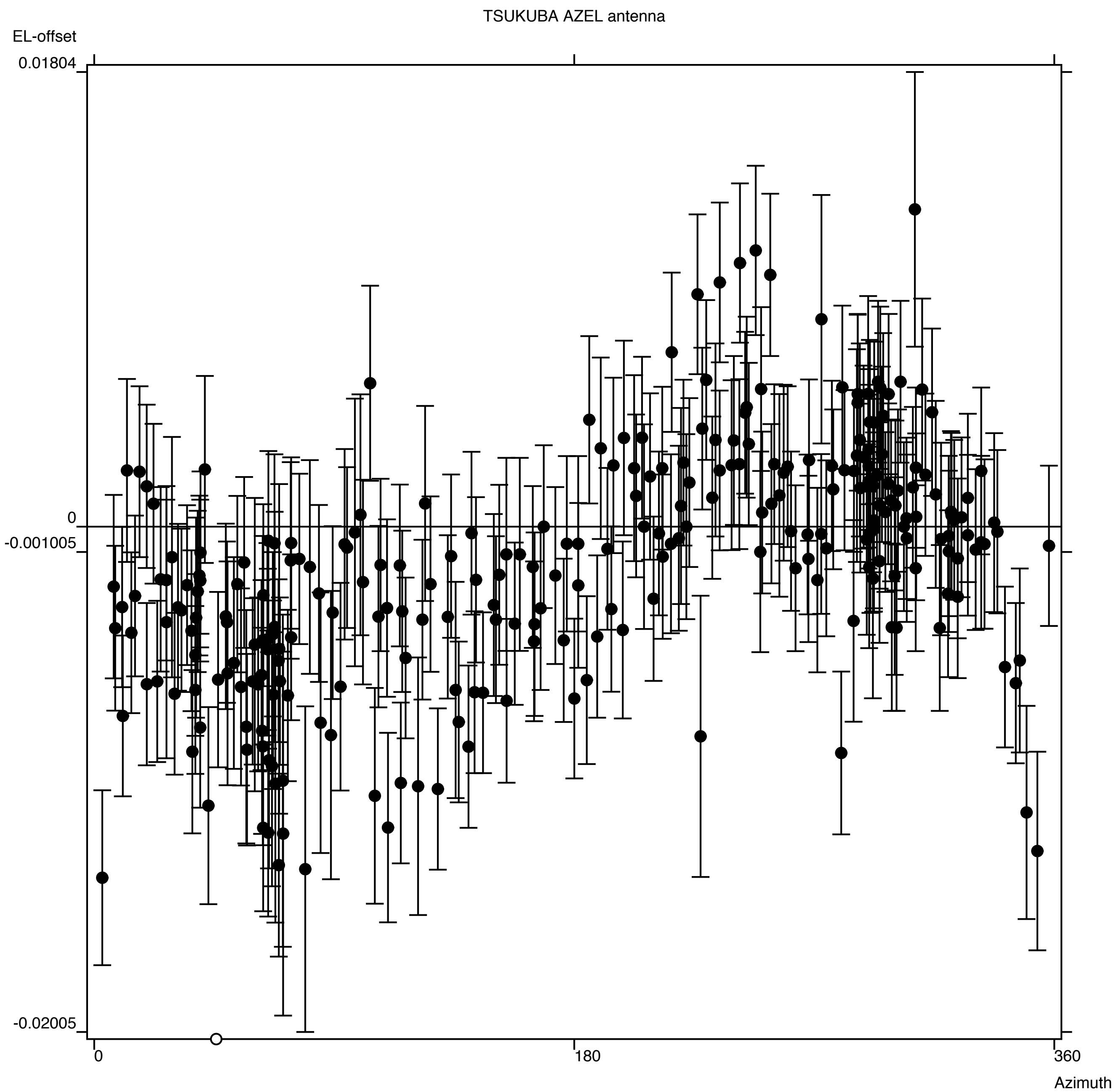
7.13 Changing model parameters

If during the analysis of the data, any unmodeled systematics are discovered, it is possible to modify the form of the model to remove them. The default model has several parameters beyond the basic eight. These can be turned on and off in the analysis by using the `Modify Parameters` item in the `Edit` main menu. There is a `Parameter Explanation` page to help identify the parameters. After making any changes, it is necessary to select `Reprocess` on the `Edit` main menu to see the results. Please note that making changes here does not permanently change the values used in the `mdlpo.ctl` file. It only changes parameters used for the current analysis session with `pdplt`. However, if you change the parameter settings, save the results of an analysis with them, and then update the `mdlpo.ctl` file, the new model in the `mdlpo.ctl` file will use the new parameter configuration. This behavior is automatic and is generally the most useful. For more information on the flags and their values and the parameters that are available, see the Pointing Model File manual (ACP Files) in Vol. 2 of the FS manuals. If the parameters that are available are not sufficient, they can be expanded, please contact Ed (Ed.Himwich@nasa.gov) for more information.

Sky Coverage

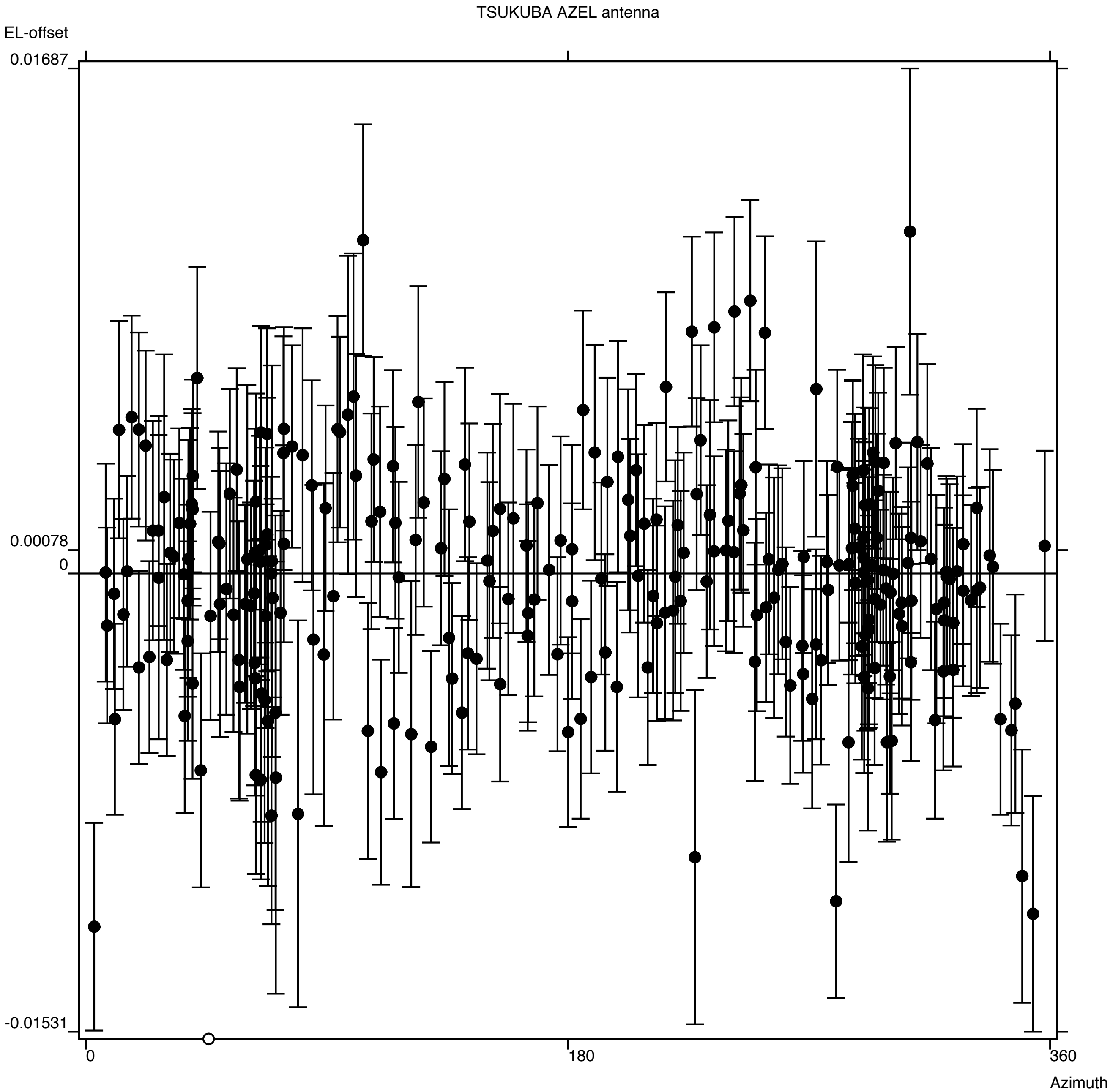


Raw Data



TSUKUBA AZEL antenna
EL-offset
0.01804
0
-0.001005
-0.02005
0
180
360
Azimuth

Residuals



TSUKUBA AZEL antenna
EL-offset
0.01687
0.00078
0
-0.01531
0
180
360
Azimuth