10. Suncal Utility

The sun may serve as an external radiation source for calibration of a radar system. This technique is simple and requires no external hardware to the radar system. The sun's position can be calculated from any point on Earth at any given time provided that accurate time and lat/lon information is known. This provides a convenient check for the antenna pointing accuracy. The sun's power can also be a useful technique for monitoring the calibration of the receive chain of the radar when used in conjunction with independent measurements of solar flux density. Solar flux densities are known to vary with frequency and are measured accurately over the 100 to 10000 MHz band from various solar observatories. Antenna beamwidth can also be computed from sector scans of the sun

The **suncal** utility is a stand-alone program that performs sector scans of the sun's position and outputs calibration data. The utility is supplied with both the RDA and IRIS releases and will work with the RVP7 and RVP8 signal processors and any antenna controller accessible via the antenna library. The **suncal** utility can be run interactively from a command line and does not use a graphical interface. It can also be inserted into the Task Scheduler as an Exec Task and run on a routine basis.

The **suncal** utility outputs a BEAM product. The BEAM product will contain SNR data with no thresholding and can be viewed on an IRIS system, but is not automatically inserted into an IRIS product directory. The BEAM product is then processed to produce a final calibration results file.

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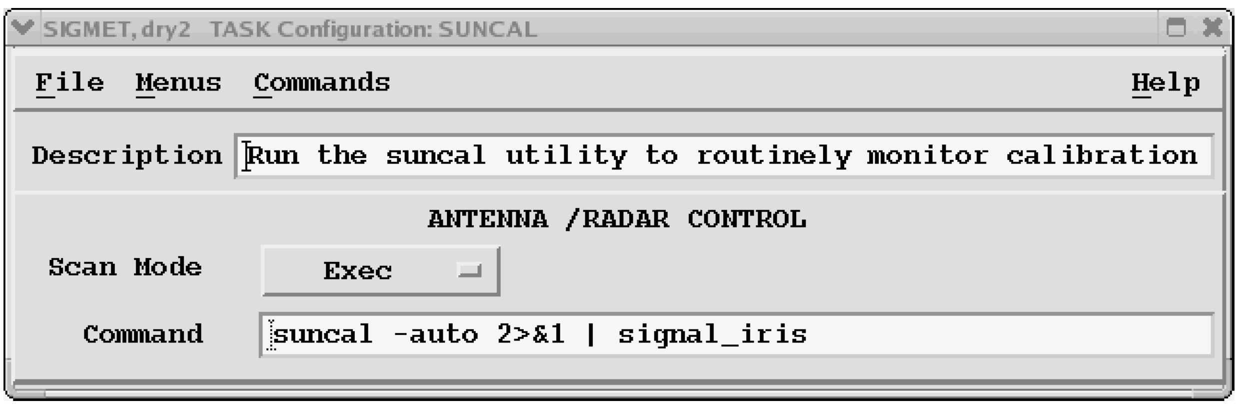
10.1 Invoking Suncal and Options

Command

$ suncal

Suncal was designed without a graphical utility so it can be run as an IRIS Exec Task. When running automatically from the IRIS task scheduler **suncal** will produce an IRIS error message if either the measured sun peak power is below a specified threshold, the antenna offset errors are larger than desired, or the sun is not high enough above the horizon when the utility was invoked. This is useful for running **suncal** routinely without operator interaction and still being able to monitor the calibration of the receive chain. The –auto option is normally given when running as an Exec Task to preclude output to a terminal window. The “2>&1 | signal_iris” command will cause IRIS to signal the error output from suncal.

Suncal Exec Task



Suncal may also be run interactively from the command line. If run interactively, the current status is reported on the terminal as well as reporting the calibration results. There is also an option to process an input BEAM product that may have been created at some earlier date. This is useful for remote testing. For example, a user can run **suncal** and then send Sigmet the resulting BEAM product which we can then process for analysis.

Table 10–1 lists the command line options to the **suncal** utility.

Table 10–1: Suncal Command Line Options

–auto	Do not log progress on the terminal.
–beam:<path>	Process an existing BEAM product.
–help	Print this list.

–resave Reads and saves the suncal.conf file with comments and all new fields filled with default values.

10.2 How Suncal Works

Solar scans are capable of providing the user with antenna pointing offset, antenna beam width measurements, and receive chain calibration. Variation in the solar flux of the sun has little effect on the antenna pointing and beamwidth measurements. Changes in the solar flux density will impact the power measured by the receiver. However independent measurements of the solar flux density can be used to verify changes in relative peak power and also calculations of the antenna gain for a radar system. This section will explain the procedure used by **suncal** to measure these quantities.

10.2.1 Antenna Scanning Sequence

The **suncal** utility accesses the antenna library to determine the location of the sun in the sky. The current UTC time is taken from the local computer system's time to compute the sun's position. You should be sure to check that the time is correct to within a few seconds. A "SUNCAL" PPI sector scan is created and starts centered at the sun's initial position minus half of the elevation span given in the suncal.conf file. This scan will start below the sun's position. It will scan back and forth at the resolution requested in the file. The user has control of the PRF, sample size, range bin spacing and number of bins. This task is not angle synced. The azimuth scan speed is half that implied by the requested PRF and sample size. The data nearest to the desired azimuths will be stored. The first defined pulse width of the signal processor is used. The quality if the sun calibration should not be effected by different pulse widths because the sun is broad band just like the noise. The recorded data is SNR (which in IRIS is dBT with range normalization turned off).

To account for the sun's movement during the scan some corrections need to be made so the output is similar to a non-moving radiation source. To do this the sun's position will be recalculated at the start of each sweep. The change in the sun's position will be subtracted from all angles for that sweep. This correction is output to the terminal window during each sweep when run interactively. For example, if the sun moved towards the horizon by 0.10 degree during the "SUNCAL" task and there were five sweeps the elevation angle increment of each sweep would be numerically decreased by approximately 0.02 degrees. Similar angle corrections are done in the azimuth direction.

10.2.2 BEAM Product Generation

An IRIS BEAM product is automatically produced upon the completion of the sector scan. This BEAM product will range average most of the bins. You can selectively skip nearby bins to avoid clutter. The azimuth and elevation limits of the BEAM product are chosen to be slightly larger than your sector scan. The BEAM product is placed in the specified directory. If you have an IRIS system running, then a nice plan is to place this in the /usr/iris_data/input directory, and configure a blank input pipe to read them. This means you can display them in IRIS. If you do not have IRIS, you can still use our **productx** utility to view the BEAM product numerically.

10.2.3 Calculating Results from BEAM

The measured location of the sun in the BEAM product is calculated by first thresholding the data above a certain signal to noise level which is configured in the suncal.conf file. A power weighted average position is computed from the passed pixels. The weighted average position is then compared to the sun's calculated position at the start of the scan and antenna pointing offsets are given in both azimuth and elevation. The peak power of the sun measurement, and target beamwidth are determined by fitting a Gaussian curve to the SNR data and finding the peak and width. Note that the azimuthal target beamwidth will be larger than expected by 1/cosine of the elevation angle because an azimuth degree corresponds to less than a degree of a great circle as you get nearer to the zenith. The "Raw" value is what is measured from the BEAM product. The other value is corrected for this effect. The peak power is also converted to dBm and stored in the results.

10.3 Using Suncal Results

The calibration results file produced contains lots of information derived from the calibration. For starters there is housekeeping information about the radar, such as the time, location, and site name. Also there is radar calibration numbers such as the noise level and the receiver bandwidth. Finally there are the numbers calculated from the sun. This includes the observed position of the sun, the pedestal angle errors, the area of the sun above threshold, the beam widths, and the peak power of the sun. Below please find an example results file. Your results file may be slightly different due to additional new fields.

```
results.sVersion = ″8.10″
results.sSitename16 = ″SIGMET, dry2″
results.sSitename3 = ″DRY″
results.VolumeYmds.isec = 80657
results.VolumeYmds.imills = 2915
results.VolumeYmds.iyear = 2006
results.VolumeYmds.imon = 3
results.VolumeYmds.iday = 24
results.BeamYmds.isec = 80709
results.BeamYmds.imills = 2374
results.BeamYmds.iyear = 2006
results.BeamYmds.imon = 3
results.BeamYmds.iday = 24
results.FileYmds.isec = 80709
results.FileYmds.imills = 2382
results.FileYmds.iyear = 2006
results.FileYmds.imon = 3
```

```
results.FileYmds.iday = 24
results.fRadarLon = –70.99999996
results.fRadarLat = 41.10000003
# Expected location of the sun.
results.fSunAzPos = 266.975497
results.fSunElPos = 5.957126711

# Measured location in BEAM product.
results.fTargetAzPos = 266.9748183
results.fTargetElPos = 5.714196538
results.fAzError = –0.0006787271701
results.fElError = –0.2429301729
results.fTargetArea = 1.184400034
results.fTargetPowerSnr = –2.853870588
results.fTargetPowerTotal = –80.18631575
results.fTargetPowerSun = –84.85387059
results.fTargetWidthAzRaw = 1.16969352
results.fTargetWidthAz = 1.16337711
results.fTargetWidthEl = 1.209176385
results.fFitError = 0.2668134805

# Calibration numbers.
results.fI0Horiz = –81.15
results.fCalNoiseHoriz = –79.98
results.fRadarConstantHoriz = –33.26
results.fActNoiseHoriz = –82
results.fReceiverBandwidth = 1
```

The antenna offset errors can than be used to adjust axis offsets in the RCP8 and the beamwidth can be used to verify manufacturer’s stated widths.

10.3.1 Antenna Beam Width Calculation

The target width measured by suncal is a function both of the antenna beamwidth and of the width of the sun. If both signals were Gaussian, it would be a simple matter to correct for the sun’s width. Unfortunately the sun is a disk of constant power, and the background noise is within a few dB. Here is a table for approximate conversions:

Table 10–2: Antenna and Sun Beamwidths

Antenna Beamwidth (Degrees)	Measured Beamwidth (Degrees)	Difference
0.200	0.522	0.322
0.300	0.534	0.234
0.400	0.574	0.174
0.500	0.636	0.136
0.600	0.711	0.111
0.700	0.794	0.094
0.800	0.881	0.081
0.900	0.972	0.072
1.000	1.064	0.064
1.100	1.158	0.058
1.200	1.253	0.053

Table 10–2: Antenna and Sun Beamwidths

Antenna Beamwidth (Degrees)	Measured Beamwidth (Degrees)	Difference
1.300	1.349	0.049
1.400	1.445	0.045
1.500	1.542	0.042
1.600	1.640	0.040
1.700	1.738	0.038
1.800	1.835	0.035
1.900	1.938	0.033
2.000	2.035	0.031

10.3.2 Using Results to Calculate Antenna Gain

The solar peak power can be used to compute the gain of the antenna. This gain can be monitored over time to determine the stability of the receiver calibration.

For solar calibration antenna gain can be written as:

$$G = \frac{4\pi \times P_s}{F_s \; B_n \; \lambda^2}$$

where,

G	Antenna gain (dimensionless) on beam axis.
P_s	Received Sun Peak Power (dBm) (fTargetPowerSun)
F_s	Solar Flux Density ($Wm^{-2} \; Hz^{-1}$)
B_n	Noise Bandwidth (Hz) (fReceiverBandwidth)
λ^2	Transmit Wavelength (m)

The calculated antenna gain must be corrected to determine the true gain of the system. Solar flux measurements include all polarizations so 3dB must be added to the gain as half the power is lost due to receiving in a single polarization. An additional beam filling correction must be made because the sun radio diameter ($0.56–0.58^0$) is considerably smaller than most antenna's 3dB beamwidth. A beam filling correction for Gaussian main beams is given below:

$$K(dB) = 20\log\left(1 + 0.18\left(\frac{U_s}{U_a}\right)^2\right)$$

For example, a 1.0^0 beam will have a filling correction of 0.49 dB. Experience has shown about ∓ 0.5 dB fluctuation in true antenna gain due to solar flux and receiver measurement uncertainties.

Observations of solar flux density (F_s) are available publicly on the internet for several frequencies, locations, and times of day. Suggested sites are the Solar Environment Center (SEC), National Oceanic and Atmospheric Administration in Boulder, Colorado; the Dominion Radio Astrophysical Observatory at Penticton, British Columbia, and the IPS Radio and Space Services Observatory in Australia.

If you wish to read the suncal results file into the C++ memory structure, you can use our supplied LoadSuncalResults() function.

10.4 The Suncal Configuration File

The **suncal** utility uses information within the **suncal.conf** file stored in the ${IRIS_CONFIG} directory. Users can adjust their configuration by editing this file with a text editor such as emacs or vi. In the file users can input the details of the scanning strategy, data output directories, whether to create a log file, and iris messaging signal thresholds. Optional sun simulation is built in to the utility to help testing. Be sure to turn this off for operation.

Running the **suncal** utility with the –resave options will read in the old **suncal.conf** file, fill in all new fields with default values, then write out the file including comments. You can run “suncal –resave” when there is no file to create a default file. It is a good idea to do this also whenever you are first using **suncal** after an upgrade. The user can then change parameters within the **suncal.conf** file to suit their needs. When designing the sector task, remember that currently tasks are limited to 40 elevation angles.

The options to create logging while the suncal utility runs, the source of the angle tags, simulation, and minimum sun angle are found at the top of the file. The **suncal** utility also checks the elevation angles to ensure they are not outside the position limits of the antenna. A maximum sun angle of 85 degrees has been hard coded into the utility. The following section shows an example of the suncal.conf file where these fields are configured.

```
sun_cal.sVersion = ""
sun_cal.lLogToFile = 1
sun_cal.lLogToTerm = 0
# 1=RVP Tags, 3=Antlib.
sun_cal.iAngleSource = 1
# Add a simulated sun, set to 0 for operation.
sun_cal.lSimulateSun = 0
# Will not run if the sun is below this angle in degrees.
sun_cal.fMinimumSunEl = 5
```

In the section of the suncal.conf below are the options to configure the PRF, range bin spacing (km), number of input bins, and pulse samples. The azimuth scan speed is half that implied by the requested PRF and sample size.

```
# Configure the recording task here.
sun_cal.fPrf = 800
sun_cal.fRangeStart = 1
sun_cal.fRangeStep = 0.150000006
sun_cal.iBinCount = 1000
sun_cal.iSampleSize = 64
```

In the next section the resolution and sector span are configured for azimuth and elevation in degrees. The SweepStartErr and SweepStartVel are the maximum allowed error in the requested antenna position and velocity in degrees and deg/sec, respectively. The MinimumVel and MinimumWait. are the minimum expected moving speed and settling time between sweeps for azimuth and elevation. Please see section 9.7.3 for more information.

```
# Spacing between rays in degrees.
sun_cal.Az.fSpacing = 0.200000003
# Span of the sector in degrees.
sun_cal.Az.fSpan = 8
sun_cal.Az.fSweepStartErr = 0.25
sun_cal.Az.fSweepStartVel = 0.5
sun_cal.Az.fMinimumVel = 10
sun_cal.Az.fMinimumWait = 0
# Spacing between rays in degrees.
sun_cal.El.fSpacing = 0.200000003
# Span of the sector in degrees.
sun_cal.El.fSpan = 8
sun_cal.El.fSweepStartErr = 0.25
sun_cal.El.fSweepStartVel = 0.5
sun_cal.El.fMinimumVel = 10
sun_cal.El.fMinimumWait = 0
```

The final section of the suncal.conf file configures the BEAM product and data qualifies to the results. In this section a directory to write the BEAM product is configured. If the BEAM product is inserted into the ${IRIS_PRODUCT} directory it will be eventually removed by the watchdog process. It is likely a better choice to put the BEAM product somewhere else to retained for future reference. To view the BEAM product in the QLW, then a nice plan is to place this in the /usr/iris_data/input directory, and configure a blank input pipe to read them. The BeamRangeStart field determines the starting range of the BEAM product. It is suggested to start the product at least 10 km from the radar to ensure no ground clutter is present.

```
# Configure the BEAM product here.
# Write the beam product to this directory.
sun_cal.sBeamDirectory = "./"
# Range to start averaging at:
sun_cal.fBeamRangeStart = 20

# Configure the results processing here.
# Write the results file to this directory.
sun_cal.sResultsDirectory = "./"
sun_cal.fBeamPower = –2
sun_cal.fBeamArea = 1
sun_cal.fBeamPowerThresh = 0
sun_cal.fBeamPosThresh = 0.5
```