9. Reference Data sets

The *FIRAS* data processing software has been designed so that the values of many parameters that affect how the programs operate are read from reference data sets. This design has allowed the modification of the values contained in the reference data sets without modifying data processing programs. A number of the parameters which comprise these reference data sets are contained in project data sets previously discussed. Several additional reference data sets may be of use in understanding how the *FIRAS* data have been processed. These data sets, which are in both ASCII and VAX binary file formats, are discussed below and are part of the *FIRAS* project data set release.

9.1. ASCII Format Reference Data sets

Glitch Rate Correction Parameters. Glitches add substantially to the noise in the data. Consequently, high glitch rate data are deweighted with respect to low glitch rate data. As described in Section 4.4, a linear least squares fit to the average variance and glitch rate of each calibrated sky spectrum generated a set of corrections for the numbers of IFGS in the *FIRAS* spectra. These corrections are shown in Table 4.8 and are listed in the reference data set FEX_GLTCHCOR.TXT given in Appendix I.

Vibration Correction Frequency Offset Indices. The calibration of the *FIRAS* spectra includes corrections for coherent vibrations (Sections 5.3.2 and 7.9.1). These corrections are applied at channel- and scan mode-specific offsets in frequency from the vibrations (Section 5.6). These offset indices are listed in the reference data set FEX_VIBCORRL.TXT given in Appendix I.

Actual Values of Commanded Instrument Gains. The coaddition program normalized the interferograms by the preamplifier gain before averaging them together, as discussed in Section 4.4. The values of the commanded gains for each channel are listed in the reference data set FEX_CMDGAIN.TXT given in Appendix I.

Mirror Transport Mechanism Sampling Rate. As discussed in Section 2, the Mirror Transport Mechanism samples the data at a fixed clockrate. This clockrate (681.43 Hz for on-orbit data, 673.29 Hz for preflight ground data) is listed in the reference data set FEX_SAMPRATE.TXT given in Appendix I.

Mirror Transport Mechanism Scan Times. As discussed in Section 2, the Mirror Transport Mechanism takes an average of about 40 seconds to collect the data averaged by the instrument microprocessors into single interferograms. The time required for a single sweep of the MTM in each scan mode is listed in the reference data set FEX_MTMSWEEP.TXT given in Appendix I.

Coaddition Consistency Check Thresholds. As discussed in Section 4.4, the coaddition program verified that the members of the ensembles of coaddable interferograms were in a consistent instrument state and had a consistent shape. The threshold values and tolerances used for these consistency checks are listed in the reference data set FEX_CTH.TXT given in Appendix I.

The following instrument state parameters were evaluated for the instrument state consistency check:

1. channel, scan mode, adds per group, number of MTM sweeps
2. attitude
3. bolometer voltage
4. GRT temperatures, spatial gradients, and temporal gradients

The following quantities determined whether or not secondary template formation and subtraction occurred:

1. amplitude and signal-to-noise ratio of primary template
2. amplitude and signal-to-noise ratio of secondary template.

Deglitching occurred after primary and secondary template formation and subtraction took place.

The following quantities were evaluated after deglitching for the shape consistency check:

1. interferogram noise
2. maximum number of outlier points

Minimum Number of IFGs. As discussed in Section 4.4, the coaddition program only creates templates for ensembles of interferograms containing at least three members. The minimum number of IFGs required for template formation is listed in the reference data set FEX_MINCOADD.TXT given in Appendix I.

GRT Weights for Coadded IFGs. The *FIRAS* has 24 GRTs and 8 calibration resistors mounted throughout its structure to measure the temperatures of various components of the instrument. Readings from the 24 GRTs are combined to yield ten temperatures that are used in calibrating the data. The relative weights used to combine the GRT readings for the calibration of coadded interferograms are listed in the reference data set FEX_GRTCOAWT.TXT given in Appendix I.

GRTs that are broken, are non-existent (not in the flight instrument or acting as a placeholder in the list of GRT properties), or give spurious readings have their weights set to zero, i.e. the XCAL "B" GRT and the collimator "B" GRT. GRTs that should be combined unequally are weighted accordingly. The calibration resistors also have their weights set to zero.

The Sky horn B GRT shows temperature spikes due to charged particle hits, so its weight is set to zero. The calibration program computes a lower χ^2 when the XCAL temperature is combined from the cone GRTs alone, so the XCAL A (tip) GRT has a weight of zero. The calibration program also computed a lower χ^2 when the structure temperature is read from the collimator mirror alone, so the Mirror A and Mirror B GRTs have their weights set to zero. Finally, the calibration program computes a lower χ^2 when the ICAL temperature is combined as 90% cone and 10% tip, so the ICAL A GRT has a weight of 0.1 and the ICAL B GRT has a weight of 0.9. All of the other GRTs are combined with equal weights.

GRT Weights for Raw IFGs. As discussed in Section 4.3 temperatures of various components of the *FIRAS* are used to sort raw IFGs into coaddable ensembles and to check the consistency of the members of these ensembles. The relative weights used to combine the GRT readings for the sorting and consistency checking of the raw IFGs are listed in the reference data set FEX_GRTRAWWT.TXT given in Appendix I. These weights are similar to but numerically diferent to the Coadd GRT weights, described above.

The XCAL B and Collimator B GRTs have zero weight. In general, the remaining weights are set to one since at this stage the instrument "sides" are not combined. The XCAL A and S5 GRTs are set to 0.5 for the XCAL combination, and the A side Mirror and Collimator GRTs are equally weighted for the A side structure measurement. The calibration resistors also have their weights set to zero.

GRT Low/High Current Transition Temperatures. The *FIRAS* GRTs have two temperature-dependent operating regimes. For the low-temperature regime, "low current" readings of the GRTs yield correct resistances and temperatures, while for the high-temperature regime, "high current" readings yield correct values. There are temperature transition regions for each GRT between these two regimes. The transition region midpoint and half-width for each GRT are listed in the reference data set FEX_GRTRRANS.TXT given in Appendix I.

9.2. VAX Binary Format Reference Data sets

Digital Transient Response Functions. The onboard digital filters add a transient signal to the samples at the beginning of each interferogram. As discussed in Section 4.4, the coaddition program corrects for this signal by fitting a digital transient response function to the first 128 points of the IFG and subtracting that fitted response from the IFG. The functional form of the digital transient response function is the Z-transform of the lowpass digital filter contained within the electronics transfer function (Section 5.3.1).

The *FIRAS* reference data set FEX_DTRF.DAT is a VAX binary format file which contains eight digital transient response function records, each of which is a floating-point array 128 samples long. These functions are dependent on the frequency (high or low) and the scan mode (short slow, short fast, long slow, or long fast) of the data. The Record Definition Language file for this data set is given in Appendix H.

Glitch Profiles. As discussed in Section 4.4 charged particles incident on the *FIRAS* bolometers give rise to "glitches" in the interferograms. The charged particles deposit a spike of energy in the detectors, giving rise to a delta function response on the part of the detectors. Consequently, the glitch spectrum is the product of the instrument electronics transfer function and the detector transfer function:

$$GS(\omega) \;=\; \frac{Z(\omega)}{1\,+\,i\omega\tau} \tag{51}$$

where ω is the audio frequency of the instrument, $Z(\omega)$ is the electronics transfer function and τ is the detector time constant. The audio frequency ω in rad/s is related to the optical frequency ν in cm^{-1} by the MTM scan speed v in cm/s:

$$\omega \;=\; v\,\nu \tag{52}$$

The glitch profile in the time domain is the inverse Fourier transform of the glitch spectrum:

$$GP(x) \;=\; \Omega^{-1} \int_{-\infty}^{+\infty} d\nu \, e^{-2\pi i\nu x} \, \frac{Z(v\nu)}{1 \,+\, iv\nu\tau} \tag{53}$$

where Ω is the normalization of the transform. As discussed in Section 4.4, the coaddition program uses the glitch profiles in the time domain to "deglitch" the interferograms.

The *FIRAS* reference data set FEX_GLTCHPRO.DAT is a VAX binary format file which contains 312 glitch profile records in the time domain, each of which is a floating-point array 512 samples long. The first 510 points of the record store the actual glitch profile; point 511 is index of glitch peak position; and point 512 is offset from the glitch peak position to the "actual" peak position obtained by parabolic interpolation. The glitch profiles have been normalized so that they have zero integral and peak values of unity. The glitch profiles are dependent on the MTM scan speed, on the channel, and on the position of the glitch within the raw data stream (the data stream prior to on-orbit averaging by the instrument microprocessors, as discussed in Section 2). Consequently there are 26 profiles for each channel/scan speed combination. The Record Definition Language file for this data set is given in Appendix H.

Baseline Basis Vectors. Internal defocussing of the instrument gives rise to non-zero baselines in the interferograms at the ends of the Mirror Transport Mechanism sweeps. As discussed in Section 4.4, the coaddition program corrects for this baseline by fitting a fourth-order polynomial baseline to the coadded IFG and subtracting that fitted baseline from the IFG. The basis vectors for the polynomial baseline are the first five Legendre polynomials on a 512-point scale running between -255/256 and 1.0.

The *FIRAS* reference data set FEX_BASIS.DAT is a VAX binary format file which contains the five basis vectors, each of which is a double-precision array 512 samples long. The Record Definition Language file for this data set is given in Appendix H.