List of Figures

**Figure 1.1** Components of the TOA radiation budget for the Earth and its atmosphere. 103

**Figure 2.1** Components of a general radiometric system. 104

**Figure 2.2** Off-axis optical system. 105

**Figure 2.3** Cassegrain optical system. 106

**Figure 2.4** Ideal behavior of thermal detectors and photon counters. 107

**Figure 2.5** Illustration of overlap in instantaneous footprints for an instrument
which scans perpendicular to the orbital direction.

**Figure 2.6** Illustration of aliasing error. On the left, the sampling frequency is seven times the original frequency; while on the right, the sampling frequency is 7/5 of the original frequency [39].

**Figure 2.7** Illustration of zenith, $\theta$, and azimuth, $\phi$, angles used to define the instrument field-of-view.

**Figure 3.1** CERES instrument package.

**Figure 3.2** Elevation scan profiles for the CERES Proto-Flight Model (PFM) located on the Tropical Rainfall Measuring Mission (TRMM) spacecraft.

**Figure 3.3** Cross-sectional view of a CERES instrument.

**Figure 3.4** Illustration of footprint scan patterns for (a) normal cross-track scan mode, and (b) biaxial scan mode.

**Figure 3.5** A CERES radiometric channel.

**Figure 3.6** End-to-end spectral response for the CERES PFM radiometric channels.

**Figure 3.7** Truncated diamond precision aperture for the CERES radiometric channels.
<table>
<thead>
<tr>
<th>Figure 3.8</th>
<th>CERES Proto-Flight Model detector nominal specifications.</th>
<th>118</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 3.9</td>
<td>CERES Proto-Flight Model pre-amplifier electronic circuit.</td>
<td>119</td>
</tr>
<tr>
<td>Figure 3.10</td>
<td>CERES Four-pole Bessel filter.</td>
<td>120</td>
</tr>
<tr>
<td>Figure 3.11</td>
<td>Computed bode plot for the CERES 4-pole Bessel filter.</td>
<td>121</td>
</tr>
<tr>
<td>Figure 3.12</td>
<td>Computed phase angle plot for the CERES four-pole Bessel filter.</td>
<td>122</td>
</tr>
<tr>
<td>Figure 3.13</td>
<td>Filtering function for the CERES 4-pole Bessel filter.</td>
<td>123</td>
</tr>
<tr>
<td>Figure 3.14</td>
<td>TRW’s Radiometric Calibration Facility (RCF) used in the CERES ground calibration [18].</td>
<td>124</td>
</tr>
<tr>
<td>Figure 3.15</td>
<td>Narrow Field Black Body (NFBB) used in the CERES Radiometric Calibration Facility (RCF) [18].</td>
<td>125</td>
</tr>
<tr>
<td>Figure 3.16</td>
<td>CERES Internal Calibration Source (ICS) module [18].</td>
<td>126</td>
</tr>
<tr>
<td>Figure 4.1</td>
<td>Schematic of the Detector Module Assembly (Not To Scale).</td>
<td>127</td>
</tr>
<tr>
<td>Figure 4.2</td>
<td>Illustration of the modeled boundary conditions.</td>
<td>128</td>
</tr>
<tr>
<td>Figure 5.1</td>
<td>Comparison of time response functions for a theoretical first-order response, for the baseline numerical model, and for the actual PFM total channel flight sensor.</td>
<td>129</td>
</tr>
</tbody>
</table>
Figure 5.2 Conceptual comparison of temperature profiles for (a) actual interface resistance, and (b) modeled interface resistance.

Figure 5.3 Predicted effect of varying the effective thermal conductivity of the Indium layer on the normalized time response function of the CERES detector module assembly.

Figure 5.4 Comparison between the CERES PFM total channel sensor response functions and the “best-fit” numerical model.

Figure 5.5 Qualitative comparison between a numerically simulated step input from the “best fit” numerical model and chopped data from the Short Wave Reference Source (SWRS) calibration for the PFM total channel.

Figure 5.6 Relationship between the longwave filtered and unfiltered radiances from the radiometric ground calibration for the PFM total channel.

Figure 5.7 Calculation of $A_v^{-1}$ based on the radiometric ground calibration for the PFM total channel sensor.

Figure 5.8 Comparison of the ideal model normalized response function with the response function from the “best fit” model version.

Figure 5.9 Effective increase in responsivity due to varying the value of thermal conductivity, $k$ (Wm$^{-1}$K$^{-1}$), for the Indium interface.

Figure 5.10 Curve fits to the ideal detector response, $u(t)$, and the predicted as-built detector response, $w(t)$.
Figure 5.11 Validation of the slow-mode numerical filtering algorithm for a step input at time, t=0.

Figure 5.12 Validation of the slow mode filtering algorithm for a nominal Earth scene.

Figure 5.13 Effectiveness of slow-mode numerical filter in forcing the “best fit” model to respond in the same fashion as the ideal model for the radiative input displayed in Figure 5.12.

Figure 5.14 Definition of various angles used in the discretization of the field-of-view into discrete solid angles.

Figure 5.15 Predicted and measured attenuation at the edge of the optical field for the PFM total channel.

Figure 5.16 Comparison of attenuation for a theoretical effective blur circle and the predicted attenuation in the scan direction from the ray-trace module.

Figure 5.17 The predicted Optical Point Spread Function (OPSF) for the CERES PFM total channel in (a) topographical, and (b) three-dimensional representations.

Figure 5.18 Illustration of trace lines used by TRW to measure the PFM total channel instrument point spread function.
Figure 5.19  Topographical representation of a point spread function for a generic scanning instrument.  147

Figure 5.20  Discretization of the instrument point spread function with an equi-angular 16-by-16 grid.  148

Figure 5.21  Predicted dynamic instrument point spread function of the CERES PFM total channel for a nominal scan rate of 63.5 deg/s in (a) topographical, and (b) three-dimensional representations.  149

Figure 5.22  Comparison between an experimentally measured and numerically predicted point spread function trace line taken along the 0-deg cross-scan plane.  150

Figure 5.23  Predicted dynamic instrument point spread function of the CERES PFM total channel for a nominal scan rate of 254 deg/s in (a) topographical, and (b) three-dimensional representations.  151

Figure 5.24  Comparison of trace lines from the rapid retrace, 254 deg/s, and normal, 63.5 deg/s, point spread functions. The trace lines correspond to a cross-scan angle of 0 deg.  152

Figure 5.25  Topographical comparison of the instrument point spread function for the (a) normal scan rate of 63.5 deg/s and the (b) rapid retrace rate of 254 deg/s.  153
Figure 5.26  Predicted (a) Bode (b) phase angle diagram for the CERES PFM total channel sensor based on the numerical end-to-end model. 154

Figure 5.27  (a) Normalized input used to assess the effectiveness of the low-pass filtering, and (b) end-to-end model output corresponding to the input seen in (a). 155

Figure 5.28  Comparison of the predicted output of the end-to-end model for a 10-Hz input and a superimposed 10- and 30-Hz input. 156

Figure 5.29  50-by-50 km Earth scene modules used in Villeneuve’s Atmospheric Radiation Transfer model [32]. 157

Figure 5.30  500-km mosaic TOA strip constructed from ten 50-by-50 km modules [32]. 158

Figure 5.31  Virtual satellite scanning a 500-km TOA strip from three different orbital positions [32]. 159

Figure 5.32  Ratios of average radiance arriving at the aperture to the power arriving at the active flake for three effective fields-of-view for the CERES sensors. 160

Figure 5.33  Determination of the optimal instantaneous field-of-view for the CERES flight sensors. 161

Figure 5.34  Illustration of two extreme weightings of the dynamic instrument point spread function used to assess the sensitivity of recovered TOA flux to point spread function weighting. In (a) all 16-by-16
bins are assigned a weighting of $\frac{1}{256}$, in (b) the four central bins are assigned a weighting of $\frac{1}{4}$.

**Figure 5.35** ERBE shortwave TOA fluxes (Wm$^{-2}$) determined using ERBE Pathfinder CERES-like data processing algorithms and an equally weighted 16-by-16 PSF array.

**Figure 5.36** Difference in calculated ERBE SW TOA flux (Wm$^{-2}$) for the two weightings of the PSF displayed in Fig. 5.34.

**Figure 5.37** Results of using an autoregressive model to recover a 20-Hz scene. The model was formulated with $n=4$, $N=12$, and the $A_i$ coefficients determined with a 10-Hz source.