HIRDLS

SP-HIR-154A

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

Originator: J.J. Barnett

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Title: **OUT-OF-BAND SPECTRAL BLOCKING REQUIREMENTS**

Description/Summary/Contents:

NOTE 1

Three computer files accompany, and are formally part of, this document . They are called:

SP-HIR-154_ANN2.TXT
SP-HIR-154_02CM_ABSPTN.CSV
SP-HIR-154_10CM_ABSPTN.CSV

They are co-located with the archive copy of this document on server:

clas/documents/sp/sp-hir-154

NOTE 2

This document was originally indexed as TC-OXF-41C, dated 25 Feb 1994.

Keywords: filter; blocking; spectral; out_of_band

Oxford University
Department of Atmospheric, Oceanic, and Planetary Physics
Parks Road
Oxford OX1 3PU, United Kingdom

University of Colorado at Boulder
Center for Limb Atmospheric Sounding
3300 Mitchell Lane, Suite 250
Boulder, Colorado 80301-2296
United States of America

EOS

1. Blocking Requirements

The HIRDLS Instrument Requirements Document (IRD) (SP-HIR-18) gives the requirements for the spectral response of the HIRDLS optical system to be:

> 2.4.3 Out-of-Band Response
>
> The out-of-band response is defined as the total integrated response outside of the points where the relative spectral response is 0.2%. When viewing the atmosphere over the sounding ranges listed in Table 2, the out-of-band radiance must be at most the greater of: (1) 1% of the in-band radiance or (2) 200% of the radiometric noise specified in Table 1 (TBV), with 50% as the design goal. When viewing the in-flight calibration (IFC) blackbody, the out-of-band radiance must be at most 1% of the in-band radiance. These requirements must be maintained over the operational lifetime of the instrument in orbit.'
>
> Calculations given here are based on the design goal given above (i.e. 50% of radiometric noise), as opposed to the hard requirement (200%). In this note the term blocking is used to refer to the reduction of out-of-band radiance to acceptable levels.

2. Spectral Calculations for Grey Blocking

This section deals with the simple idealised case, which is for an out-of-band response that is independent of frequency. In this case it is possible to calculate the single value of out-of-band transmission that will meet the requirements for a given channel. The requirements will be different for viewing the atmosphere and the calibration target, and the most severe will need to be used.

The calculations have been performed between 350 and 2140 cm-1. These wavenumber limits were chosen because it was assumed that optical components could be selected which were opaque elsewhere. The proportions of the total integrated Planck funtion that fall within these regions are given in Table 1.

TABLE 1

Wavenumber interval (cm-1)	Temperature (K) 200	250	300
<350	0.29	0.18	0.12
350-2140	0.71	0.81	0.87
>2140	1.4E-4	1.7E-3	7.9E-3

The calculations used means over 10 cm-1 intervals of the limb path absorption of the important gaseous absorbers calculated every 0.0005 cm-1 by line-by-line methods. Tabulations were available for heights of 10, 20, 30, 40, 50, 60 and 70 km. The emission for each 10 cm-1 interval for a given height was obtained by multiplying the limb opacity for that tangent height by the Planck function at that height. This is a valid approximation for most optically thin (i.e. low opacity) cases, which are relevant for most of the heights and frequencies considered here. Where the opacity approaches unity this approximation uses a temperature for too low a tangent height. For each channel the radiance was integrated over the nominal 50% points passband (interpolating between 10 cm-1 points as necessary); this is called the 'in-band radiance'. This was compared with that integrated over the whole spectral range but excluding the nominal passband, denoted the 'out-of-band radiance'

It is required that the out-of-band radiance should not exceed 1% of the in-band radiance. However at high altitudes where the in-band radiance becomes very small this criterion requires an out-of-band radiance that may be so small as to be totally unmeasurable hence unimportant. Consequently the out-of-band radiance is not required to be less than 0.5 of the specified noise equivalent

radiance (NEN) of the channel in question. Values of NEN obtained from the Instrument Requirements Document are given in Table 2. The value of out-of-band rejection relative to mean in-band transmission was then calculated as MAX(0.01*in-band, NEN*0.5) / (out-of-band).

The calculations were performed for each tangent height for which the Instrument Requirements Document specifies that atmospheric radiances are to be measured. These heights are reproduced in Table 2. It should be noted that for several channels (notably the aerosol channels) the range extends higher than levels where significant emissions are normally expected. The lowest rejection value is given in Table 2 as being that necessary to meet the requirements for viewing the atmosphere throughout the specified height range. (Note that the value was interpolated linearly between the 10 km levels).

The calculations were also made for a 300 K black (i.e. perfectly opaque) target and the requirement presented separately in Table 2.

Inspection of Table 2 shows some interesting results. For channels 2-5 (carbon dioxide) and 11 (high altitude ozone) the black body requirements are more severe than for viewing the atmosphere. This is because the atmospheric emissions in these pass bands are much greater than the average across the spectrum. Indeed for the CO_2 bands most of the out-of-band atmospheric radiation comes from CO_2 at nearby wavelengths, so would be less of a problem (provided that the leaks were adequately measured) than out-of-band radiation from other gases. The other extreme occurs with aerosol bands. Here the in-band emission is intended to be small, and the atmospheric case needs better out-of-band rejection than the 300K black target. For the cases of emitters whose mixing ratios decrease rapidly with height (the CFCs, HNO_3, etc and also most of the window channel emitters), starting at 8 km and moving up, the out-of-band transmission requirement becomes more severe since the in-band radiance is decreasing more rapidly than the spectrum-wide average. At some height however the out-of-band requirement reaches NEN*0.5; above this height the out-of-band requirement stays constant while the in-band radiance continues to fall, so the requirements again becomes less severe. Hence in these cases the requirement is most severe at some mid point in the height range where the in-band signal is 50*NEN.

It should be re-emphasised that these out-of-band transmissions are relative to the mean transmission across the nominal passband, e.g. if the mean transmission across the passband for channel 1 were 60%, then the transmission at all wavelengths remote from the passband should be less than 60% of the figure quoted of 1.2E-4, i.e. less than 0.72E-4.

TABLE 2 - calculated maximum permissible grey out-band-transmissions for the most difficult atmospheric view and a 300K black target.

Channel Number	Height range assumed (km) (note 3)	Nominal FWHH cm-1	Target species	NEN (note 2)	Grey blocking requirements Atmosphere	300K target (note 4)
1	8-70	563- 588	N2O	12	1.2E-4	3.2E-04
2	8-40	600- 615	CO2	6.3	2.9E-4	2.0E-04
3	8-60	610- 640	CO2	5.9	1.1E-3	3.9E-04
4	15-60	626- 660	CO2	6.0	1.6E-3	4.4E-04
5	30-105	655- 680	CO2	4.3	2.4E-3	3.2E-04
6	8-55	821- 836	Aerosol	1.9	9.4E-6	1.7E-04
7	8-50	835- 853	CFC11	2.0	1.2E-5	1.9E-04
8	8-70	860- 905	HNO3	2.1	2.7E-5	4.6E-04
9	8-50	915- 933	CFC12	2.0	1.2E-5	1.7E-04
10	8-55	985-1005	O3	1.5	1.3E-4	1.7E-04
10*	8-55	990-1010	O3	1.5	1.5E-5	1.7E-04
11	30-85	1020-1070	O3	2.4	1.0E-3	3.8E-04
11*	30-85	1011-1048	O3	2.4	7.4E-4	2.9E-04
12	8-55	1120-1140	O3	0.96	3.8E-5	1.3E-04
13	8-55	1200-1220	Aerosol	1.1	6.8E-6	1.1E-04
14	8-60	1229-1260	N2O5	1.1	1.8E-5	1.5E-04
15	8-70	1256-1282	N2O	1.1	1.7E-5	1.2E-04
16	8-70	1278-1299	CLONO2	1.1	1.5E-5	9.2E-05
17	8-80	1324-1369	CH4	1.2	2.3E-5	1.7E-04
18	8-40	1385-1435	H2O	1.2	1.2E-5	1.6E-04
19	8-55	1402-1416	Aerosol	1.3	6.4E-6	4.6E-05
20	15-85	1422-1542	H2O	1.6	4.3E-5	3.1E-04
21	8-70	1582-1634	NO2	1.1	1.4E-5	9.3E-05

notes on Table 2:

1) Passband, channel number and noise equivalent radiance are those given in the Instrument Requirements Document SC-HIR-18J Table 1. The blocking requirement does not depend critically on the passband.
2) The NEN (noise equivalent radiance) is given in units of 10E-4 W/m**2/ster and is the maximum permissible standard deviation of detector noise for the specified passband for a measurement time bandwidth of 7.5 Hz. These values are taken from SC-HIR-18J Table 1.
3) The height ranges used were obtained from Table 2 of SC-HIR-18J.
4) To be consistent with the atmospheric calculations the black target calculations were performed over the same spectral interval (350-2140cm-1). Values applicable to the whole frequency range (0-infinity) could be obtained by multiplying by the value of 0.87 obtained from Table 1.
5) The two passbands marked by * (for channels 10 and 11) are alternatives that are proposed in Rev J of the IRD.

3. Frequency-dependant out-of-band transmission

The above calculations assume a grey blocker, i.e. transmission independent of frequency. Clearly it is admissible to make the blocking better than this requirement at some or all frequencies. However with a variable blocking level it is not in general sufficient just to meet this level of blocking on average over the whole spectrum since the frequencies of poorer blocking might happen to be where the atmospheric emission spectrum is strongest.

This raises the question of whether it is worth trying to maximise the blocking at critical wavelengths while allowing it to degrade at others. No way could be devised to do this optimally, mainly because this would require a value judgement of how difficult it is to provide blocking at one wavelength compared with another. However it should be noted that the major emitters at height altitude (>40 km) are carbon dioxide in the 620-730 cm-1 interval and ozone in the 990-1070 cm-1 interval, and that factors of 10 additional blocking against these species may be advantageous for channels that do not include these intervals. In addition the Planck function has very large variations over the whole spectral interval, peaking near to the long wavelength end, so the need for blocking is correspondingly greater at increasing wavelength.

In order to facilitate calculations for frequency-dependant blocking, a Lotus 123-compatible spread sheet has been produced that calculates in-band and out-of band radiances and their ratio at each height.

Annex 1 was printed from this spread sheet which contains the following data:

ROWS 1 & 2 annotation or blank
ROW 3, cols 4, 8, 12, etc: Tangent heights of limb paths (10-70 km, although 40-70 km are omitted from the printout because they could not be accommodated on the page) in appropriate columns (VALUE)
ROW 4, cols 4, 8, 12 ..28: Temperatures for these tangent heights (K) (VALUE)
ROW 4, col 32: Temperature used for black calibration target (K) (VALUE)
ROWS 5-8: annotation
ROWS 9-187 COLUMNS:
1) Frequency in cm-1 (VALUE)
2) Filter transmission to be used to calculate the in-band radiance (VALUE)
3) Filter transmission to be used to calculate the out-of-band radiance(VALUE)
4) Planck function for height given in row 3 at temperature given in row 4 (FORMULA)
5) Limb path absorption for this height and wavenumber (VALUE)
6) In band radiance (product of cols 2, 4 and 5) (FORMULA)
7) Out-of-band radiance (product of cols 3, 4 and 5) (FORMULA)
Columns 4-7 are then repeated for each of the 6 other tangent heights
32) Planck function for black target at temperature given in row 4 (FORMULA)
33) In band radiance for calibration target (product of cols 2, & 32) (FORMULA)
34) Out-of-band radiance for cal. target (product of cols 3, and 32) (FORMULA)
35) Copy of column 1 (frequency in cm-1) (FORMULA)
ROW 188 blank
ROW 189, COLUMNS:
1-5) Annotation or blank
6) Sum of in band radiance from rows 9-187 column 6 *10 (FORMULA)

7) Sum of out-of-band radiance from rows 9-187 column 6 *10 (FORMULA)
Columns 4-7 are then repeated for each of the 6 remaining tangent heights, and the calibration target in the appropriate columns.

ROW 190, COLUMNS:
1-5 Annotation or blank
7) Maximum permitted out-of-band radiance (in-band*0.01 from ROW 189 COL 6 or NEN*0.5 whichever is greater) (FORMULA)
Columns 4-7 are then repeated for each of the 6 remaining tangent heights, and the calibration target in the appropriate columns.

ROW 191, COLUMNS:
7) Margin ratio (requirement/actual out-of-band) from ROWS 190,191 col 7 i.e. >1 is required (FORMULA)
Columns 4-7 are then repeated for each of the 6 remaining tangent heights, and the calibration target in the appropriate columns.

(VALUE after an entry means that the spreadsheet cell contains a numerical value; FORMULA means that the cell contains a formula which presents a value obtained by manipulating other cell entries)

The spread sheet is used as follows:

The NEN for the channel should be entered at the top of the spreadsheet in the appropriate cell. The filter transmission to be used to calculate the in-band radiance is entered into column 2; this should be entered as zero (or left blank) outside the passband, and should have appropriate transmissions inside the passband. The table only provides for a resolution of 10 cm-1, hence the calculation will be approximate. For each wavenumber this filter transmission is automatically multiplied by the Planck function and the limb transmission for each tangent height, and the result is printed by the spread sheet formulae in columns 6, 10, 14, etc. The sum of these columns multiplied by the interval width (10 cm-1) is printed at the bottom and represents the in-band flux at each tangent height and for a black calibration target in units of mW/m**2/ster.

The out-of-band radiances are similarly calculated automatically from the blocking transmittance which is entered into column 3 (the blocking transmittance should ideally be set to zero inside the passband, although negligible error will result if some low level of transmission if carried across the passband). The radiance contributions are calculated (by multiplying the blocking transmission by the Planck function by the limb absorption) and printed in columns 7, 11, 15, etc, and the sums multiplied by the interval width given are at the bottom as the total out of band flux.

The maximum permitted out-of-band radiance is then shown (NEN*0.5 or 1.0% of the in-band radiance, whichever is the greater), and then the ratio by which the requirement is greater than that expected. These ratios should exceed 1 for all of the height range and for the calibration target.

The expectation is that the user would generate a separate copy of this spread sheet for each passband. The details of the filter and the out-of-band transmissions would be entered for each frequency (this is relatively easy using the spread sheet replication commands; if necessary the out-of-band values could be generated with a polynomial formula using a few coefficients). The spreadsheet would then calculate radiance ratios for each height. If these were unsatisfactory, the blocking curves would be modified, e.g. at wavelengths where the blocking was seen to be passing excessive radiance, until satisfactory performance was obtained at all heights.

Annex 1. Printout from spreadsheet used to calculate in-band and out-of-band responses.

This example is for Channel 10 (nominally 985-1005 cm-1 FWHH). The columns for 40, 50, 60 and 70 km are omitted because of the difficulty of printing.

Channel: 10 Target gas: Ozone NEN (mw/m**2/ster) 0.15

Height:			10 km				20 km				30 km					Black calibration target	
Temperature:			210				220				240				4	300	
Freq cm-1	filter transmn	Blocking transmn	Planck Fn	Limb absorptn	Radiances filt	unwanted	Planck Fn	Limb absorptn	Radiances filt	unwanted	Planck Fn	Limb absorptn	Radiances filt	unwanted	0 to	Planck Fn	Radiances filt unwanted	freq cm-1
355	0	0.00013	51.303	0.780	0	0.0052	57.952	0.219	0	0.00165	71.994	0.063	0	0.00059		118.700	0 0.01543	355
365	0	0.00013	51.740	0.338	0	0.00228	58.598	0.055	0	0.00042	73.123	0.013	0	0.00013	7	121.706	0 0.01582	365
375	0	0.00013	52.086	0.485	0	0.00328	59.146	0.104	0	0.0008	74.140	0.029	0	0.00028	0	124.579	0 0.0162	375
385	0	0.00013	52.345	0.360	0	0.00245	59.598	0.073	0	0.00057	75.047	0.019	0	0.00018		127.318	0 0.01655	385
395	0	0.00013	52.520	0.477	0	0.00326	59.956	0.122	0	0.00095	75.845	0.037	0	0.00037	k	129.920	0 0.01689	395
405	0	0.00013	52.613	0.158	0	0.00108	60.223	0.023	0	0.00018	76.535	0.006	0	6E-05	m	132.385	0 0.01721	405
415	0	0.00013	52.627	0.349	0	0.00239	60.403	0.097	0	0.00076	77.120	0.028	0	0.00028		134.710	0 0.01751	415
425	0	0.00013	52.566	0.249	0	0.0017	60.496	0.040	0	0.00031	77.602	0.010	0	9.9E-05	o	136.895	0 0.0178	425
435	0	0.00013	52.432	0.145	0	0.00099	60.508	0.024	0	0.00019	77.983	0.006	0	6.5E-05	m	138.939	0 0.01806	435
445	0	0.00013	52.230	0.200	0	0.00136	60.441	0.044	0	0.00035	78.266	0.013	0	0.00013	i	140.843	0 0.01831	445
455	0	0.00013	51.963	0.245	0	0.00166	60.298	0.061	0	0.00048	78.453	0.018	0	0.00018	t	142.607	0 0.01854	455
465	0	0.00013	51.634	0.076	0	0.00051	60.083	0.012	0	9.5E-05	78.549	0.004	0	4.1E-05	t	144.232	0 0.01875	465
475	0	0.00013	51.247	0.173	0	0.00115	59.799	0.043	0	0.00034	78.554	0.012	0	0.00013	e	145.718	0 0.01894	475

485	0	0.00013	50.805	0.112	0	0.00074	59.450	0.022	0	0.00017	78.474	0.006	0	6.2E-05	d	147.066	0	0.01912	485
495	0	0.00013	50.311	0.058	0	0.00038	59.039	0.010	0	7.9E-05	78.312	0.003	0	3.2E-05		148.279	0	0.01928	495
505	0	0.00013	49.770	0.138	0	0.00089	58.570	0.029	0	0.00022	78.070	0.008	0	8.4E-05		149.358	0	0.01942	505
515	0	0.00013	49.185	0.139	0	0.00089	58.046	0.030	0	0.00022	77.752	0.009	0	9.5E-05		150.305	0	0.01954	515
525	0	0.00013	48.559	0.090	0	0.00057	57.471	0.019	0	0.00014	77.362	0.006	0	5.7E-05		151.121	0	0.01965	525
535	0	0.00013	47.895	0.072	0	0.00045	56.848	0.015	0	0.00011	76.903	0.004	0	4.2E-05		151.810	0	0.01974	535
545	0	0.00013	47.196	0.212	0	0.0013	56.180	0.053	0	0.00039	76.379	0.016	0	0.00016		152.374	0	0.01981	545
555	0	0.00013	46.466	0.167	0	0.00101	55.472	0.034	0	0.00024	75.793	0.008	0	7.5E-05		152.816	0	0.01987	555
565	0	0.00013	45.708	0.420	0	0.0025	54.726	0.096	0	0.00068	75.149	0.021	0	0.0002		153.139	0	0.01991	565
575	0	0.00013	44.925	0.629	0	0.00367	53.945	0.175	0	0.00123	74.449	0.039	0	0.00038		153.344	0	0.01993	575

585 0 0.00013 | 44.119 0.839 0 0.00481 | 53.132 0.340 0 0.00235 | 73.699 0.092 0 0.00088 | |153.437 0
0.01995 | 585
595 0 0.00013 | 43.294 0.978 0 0.00551 | 52.291 0.528 0 0.00359 | 72.900 0.170 0 0.00161 | |153.419 0
0.01994 | 595
605 0 0.00013 | 42.452 0.998 0 0.00551 | 51.424 0.590 0 0.00395 | 72.057 0.169 0 0.00159 | |153.293 0
0.01993 | 605
615 0 0.00013 | 41.595 1.000 0 0.00541 | 50.535 0.749 0 0.00492 | 71.172 0.326 0 0.00302 | |153.065 0
0.0199 | 615
625 0 0.00013 | 40.726 1.000 0 0.00529 | 49.625 0.827 0 0.00533 | 70.249 0.326 0 0.00297 | |152.735 0
0.01986 | 625
635 0 0.00013 | 39.847 1.000 0 0.00518 | 48.698 0.994 0 0.00629 | 69.291 0.615 0 0.00554 | |152.309 0
0.0198 | 635
645 0 0.00013 | 38.960 1.000 0 0.00506 | 47.756 1.000 0 0.00621 | 68.301 0.838 0 0.00744 | |151.790 0
0.01973 | 645
655 0 0.00013 | 38.068 1.000 0 0.00495 | 46.802 1.000 0 0.00608 | 67.282 0.946 0 0.00827 | |151.180 0
0.01965 | 655
665 0 0.00013 | 37.173 1.000 0 0.00483 | 45.837 1.000 0 0.00596 | 66.237 0.980 0 0.00844 | |150.484 0
0.01956 | 665
675 0 0.00013 | 36.275 1.000 0 0.00472 | 44.865 1.000 0 0.00583 | 65.168 0.957 0 0.00811 | |149.705 0
0.01946 | 675
685 0 0.00013 | 35.378 1.000 0 0.0046 | 43.886 1.000 0 0.00571 | 64.078 0.909 0 0.00757 | |148.846 0
0.01935 | 685
695 0 0.00013 | 34.482 1.000 0 0.00448 | 42.904 0.999 0 0.00557 | 62.970 0.728 0 0.00596 | |147.912 0
0.01923 | 695
705 0 0.00013 | 33.590 1.000 0 0.00437 | 41.919 0.957 0 0.00522 | 61.847 0.493 0 0.00396 | |146.905 0
0.0191 | 705
715 0 0.00013 | 32.702 1.000 0 0.00425 | 40.934 0.898 0 0.00478 | 60.710 0.453 0 0.00357 | |145.829 0
0.01896 | 715
725 0 0.00013 | 31.820 0.999 0 0.00413 | 39.951 0.795 0 0.00413 | 59.562 0.399 0 0.00309 | |144.688 0
0.01881 | 725
735 0 0.00013 | 30.945 0.998 0 0.00402 | 38.970 0.704 0 0.00357 | 58.405 0.284 0 0.00216 | |143.485 0
0.01865 | 735
745 0 0.00013 | 30.079 0.931 0 0.00364 | 37.993 0.594 0 0.00293 | 57.242 0.245 0 0.00182 | |142.222 0
0.01849 | 745
755 0 0.00013 | 29.221 0.714 0 0.00271 | 37.023 0.416 0 0.002 | 56.073 0.158 0 0.00115 | |140.905 0
0.01832 | 755
765 0 0.00013 | 28.374 0.432 0 0.00159 | 36.059 0.276 0 0.00129 | 54.902 0.104 0 0.00074 | |139.535 0
0.01814 | 765
775 0 0.00013 | 27.539 0.305 0 0.00109 | 35.103 0.222 0 0.00101 | 53.730 0.084 0 0.00059 | |138.116 0
0.01796 | 775
785 0 0.00013 | 26.715 0.204 0 0.00071 | 34.157 0.155 0 0.00069 | 52.558 0.056 0 0.00038 | |136.652 0
0.01776 | 785
795 0 0.00013 | 25.903 0.292 0 0.00098 | 33.220 0.177 0 0.00076 | 51.389 0.063 0 0.00042 | |135.144 0
0.01757 | 795
805 0 0.00013 | 25.105 0.152 0 0.0005 | 32.295 0.097 0 0.00041 | 50.223 0.033 0 0.00022 | |133.597 0
0.01737 | 805
815 0 0.00013 | 24.321 0.083 0 0.00026 | 31.382 0.059 0 0.00024 | 49.062 0.021 0 0.00013 | |132.013 0
0.01716 | 815

825	0	0.00013	23.551	0.030	0	9.3E-05	30.481	0.020	0	7.7E-05	47.908	0.008	0	5.3E-05		130.396	0	0.01695	825
835	0	0.00013	22.796	0.058	0	0.00017	29.594	0.011	0	4.1E-05	46.762	0.004	0	2.2E-05		128.747	0	0.01674	835
845	0	0.00013	22.055	0.302	0	0.00087	28.721	0.029	0	0.00011	45.625	0.003	0	1.6E-05		127.070	0	0.01652	845
855	0	0.00013	21.330	0.178	0	0.00049	27.862	0.051	0	0.00018	44.497	0.008	0	4.5E-05		125.367	0	0.0163	855
865	0	0.00013	20.621	0.097	0	0.00026	27.018	0.117	0	0.00041	43.381	0.021	0	0.00012		123.642	0	0.01607	865
875	0	0.00013	19.928	0.162	0	0.00042	26.190	0.165	0	0.00056	42.276	0.030	0	0.00016		121.895	0	0.01585	875
885	0	0.00013	19.250	0.216	0	0.00054	25.378	0.204	0	0.00067	41.185	0.036	0	0.00019		120.131	0	0.01562	885
895	0	0.00013	18.589	0.196	0	0.00047	24.581	0.200	0	0.00064	40.107	0.036	0	0.00019		118.351	0	0.01539	895
905	0	0.00013	17.944	0.152	0	0.00035	23.801	0.139	0	0.00043	39.043	0.024	0	0.00012		116.557	0	0.01515	905
915	0	0.00013	17.315	0.259	0	0.00058	23.038	0.100	0	0.0003	37.994	0.015	0	7.3E-05		114.752	0	0.01492	915
925	0	0.00013	16.702	0.298	0	0.00065	22.291	0.063	0	0.00018	36.960	0.007	0	3.6E-05		112.938	0	0.01468	925
935	0	0.00013	16.106	0.139	0	0.00029	21.562	0.028	0	7.9E-05	35.943	0.005	0	2.5E-05		111.116	0	0.01445	935
945	0	0.00013	15.525	0.092	0	0.00018	20.849	0.020	0	5.5E-05	34.942	0.006	0	2.7E-05		109.289	0	0.01421	945

955	0	0.00013	14.961	0.086	0	0.00017	20.153	0.021	0	5.5E-05	33.957	0.007	0	3E-05			107.459	0	0.01397	955
965	0	0.00013	14.412	0.097	0	0.00018	19.474	0.045	0	0.00011	32.991	0.020	0	8.5E-05			105.628	0	0.01373	965
975	0	0.00013	13.880	0.218	0	0.00039	18.812	0.160	0	0.00039	32.041	0.075	0	0.00031			103.796	0	0.01349	975
985	0.5	0.00013	13.362	0.386	2.57897	0.00067	18.167	0.394	3.57982	0.00093	31.110	0.193	3.0037	0.00078			101.967	50.9834	0.01326	985
995	1	0.00013	12.860	0.652	8.38285	0.00109	17.539	0.660	11.581	0.00151	30.196	0.348	10.4975	0.00136			100.140	100.14	0.01302	995
1005	0.5	0.00013	12.374	0.892	5.51656	0.00143	16.927	0.883	7.47333	0.00194	29.301	0.535	7.83902	0.00204			98.319	49.1595	0.01278	1005
1015	0	0.00013	11.902	0.982	0	0.00152	16.332	0.975	0	0.00207	28.424	0.708	0	0.00262			96.504	0	0.01255	1015
1025	0	0.00013	11.445	0.998	0	0.00148	15.754	0.996	0	0.00204	27.566	0.804	0	0.00288			94.696	0	0.01231	1025
1035	0	0.00013	11.002	0.999	0	0.00143	15.191	0.999	0	0.00197	26.726	0.861	0	0.00299			92.898	0	0.01208	1035
1045	0	0.00013	10.574	0.962	0	0.00132	14.645	0.955	0	0.00182	25.904	0.723	0	0.00244			91.109	0	0.01184	1045
1055	0	0.00013	10.159	1.000	0	0.00132	14.115	0.999	0	0.00183	25.102	0.872	0	0.00284			89.332	0	0.01161	1055
1065	0	0.00013	9.758	0.900	0	0.00114	13.600	0.883	0	0.00156	24.317	0.594	0	0.00188			87.567	0	0.01138	1065
1075	0	0.00013	9.371	0.477	0	0.00058	13.100	0.394	0	0.00067	23.551	0.169	0	0.00052			85.816	0	0.01116	1075
1085	0	0.00013	8.997	0.500	0	0.00058	12.616	0.424	0	0.00069	22.803	0.175	0	0.00052			84.079	0	0.01093	1085
1095	0	0.00013	8.635	0.485	0	0.00054	12.146	0.364	0	0.00058	22.074	0.136	0	0.00039			82.357	0	0.01071	1095
1105	0	0.00013	8.286	0.450	0	0.00048	11.692	0.317	0	0.00048	21.363	0.116	0	0.00032			80.651	0	0.01048	1105
1115	0	0.00013	7.949	0.371	0	0.00038	11.251	0.311	0	0.00045	20.669	0.116	0	0.00031			78.962	0	0.01027	1115
1125	0	0.00013	7.624	0.367	0	0.00036	10.824	0.325	0	0.00046	19.994	0.124	0	0.00032			77.290	0	0.01005	1125
1135	0	0.00013	7.310	0.390	0	0.00037	10.411	0.320	0	0.00043	19.336	0.123	0	0.00031			75.637	0	0.00983	1135
1145	0	0.00013	7.008	0.455	0	0.00041	10.012	0.280	0	0.00036	18.695	0.099	0	0.00024			74.003	0	0.00962	1145
1155	0	0.00013	6.717	0.461	0	0.0004	9.626	0.233	0	0.00029	18.072	0.074	0	0.00017			72.388	0	0.00941	1155
1165	0	0.00013	6.436	0.368	0	0.00031	9.252	0.196	0	0.00024	17.465	0.065	0	0.00015			70.793	0	0.0092	1165
1175	0	0.00013	6.166	0.417	0	0.00033	8.892	0.187	0	0.00022	16.875	0.058	0	0.00013			69.219	0	0.009	1175
1185	0	0.00013	5.906	0.374	0	0.00029	8.543	0.149	0	0.00017	16.302	0.045	0	9.5E-05			67.665	0	0.0088	1185

1195	0	0.00013	5.655	0.259	0	0.00019	8.206	0.099	0	0.00011	15.744	0.030	0	6.2E-05			66.133	0	0.0086	1195			
1205	0	0.00013	5.415	0.171	0	0.00012	7.881	0.057	0	5.8E-05	15.203	0.017	0	3.4E-05			64.622	0	0.0084	1205			
1215	0	0.00013	5.183	0.236	0	0.00016	7.567	0.064	0	6.3E-05	14.677	0.017	0	3.3E-05			63.133	0	0.00821	1215			
1225	0	0.00013	4.960	0.351	0	0.00023	7.265	0.086	0	8.1E-05	14.167	0.021	0	3.9E-05			61.667	0	0.00802	1225			
1235	0	0.00013	4.746	0.453	0	0.00028	6.973	0.136	0	0.00012	13.671	0.042	0	7.5E-05			60.222	0	0.00783	1235			
1245	0	0.00013	4.540	0.733	0	0.00043	6.691	0.257	0	0.00022	13.191	0.081	0	0.00014			58.801	0	0.00764	1245			
1255	0	0.00013	4.342	0.833	0	0.00047	6.420	0.315	0	0.00026	12.725	0.077	0	0.00013			57.402	0	0.00746	1255			
1265	0	0.00013	4.153	0.981	0	0.00053	6.158	0.447	0	0.00036	12.273	0.079	0	0.00013			56.026	0	0.00728	1265			
1275	0	0.00013	3.970	0.994	0	0.00051	5.906	0.540	0	0.00041	11.835	0.096	0	0.00015			54.673	0	0.00711	1275			
1285	0	0.00013	3.795	0.959	0	0.00047	5.663	0.553	0	0.00041	11.410	0.116	0	0.00017			53.343	0	0.00693	1285			
1295	0	0.00013	3.627	0.995	0	0.00047	5.429	0.675	0	0.00048	10.999	0.154	0	0.00022			52.037	0	0.00676	1295			
1305	0	0.00013	3.466	0.982	0	0.00044	5.204	0.773	0	0.00052	10.600	0.231	0	0.00032			50.753	0	0.0066	1305			

1315	0	0.00013	3.312	0.876	0	0.00038	4.988	0.500	0	0.00032	10.214	0.103	0	0.00014			49.493	0	0.00643	1315
1325	0	0.00013	3.163	0.789	0	0.00032	4.779	0.472	0	0.00029	9.841	0.097	0	0.00012			48.256	0	0.00627	1325
1335	0	0.00013	3.021	0.809	0	0.00032	4.579	0.468	0	0.00028	9.480	0.103	0	0.00013			47.042	0	0.00612	1335
1345	0	0.00013	2.885	0.841	0	0.00032	4.386	0.463	0	0.00026	9.130	0.100	0	0.00012			45.851	0	0.00596	1345
1355	0	0.00013	2.755	0.797	0	0.00029	4.201	0.268	0	0.00015	8.792	0.054	0	6.2E-05			44.682	0	0.00581	1355
1365	0	0.00013	2.630	0.695	0	0.00024	4.023	0.212	0	0.00011	8.465	0.052	0	5.7E-05			43.537	0	0.00566	1365
1375	0	0.00013	2.510	0.603	0	0.0002	3.851	0.156	0	7.8E-05	8.149	0.041	0	4.3E-05			42.414	0	0.00551	1375
1385	0	0.00013	2.395	0.415	0	0.00013	3.687	0.095	0	4.6E-05	7.843	0.025	0	2.5E-05			41.314	0	0.00537	1385
1395	0	0.00013	2.285	0.521	0	0.00015	3.529	0.127	0	5.8E-05	7.548	0.036	0	3.5E-05			40.236	0	0.00523	1395
1405	0	0.00013	2.180	0.270	0	7.6E-05	3.377	0.047	0	2.1E-05	7.263	0.012	0	1.1E-05			39.181	0	0.00509	1405
1415	0	0.00013	2.080	0.473	0	0.00013	3.231	0.139	0	5.9E-05	6.987	0.042	0	3.8E-05			38.147	0	0.00496	1415
1425	0	0.00013	1.983	0.537	0	0.00014	3.091	0.106	0	4.3E-05	6.721	0.025	0	2.2E-05			37.135	0	0.00483	1425
1435	0	0.00013	1.891	0.689	0	0.00017	2.957	0.153	0	5.9E-05	6.464	0.040	0	3.4E-05			36.145	0	0.0047	1435
1445	0	0.00013	1.803	0.684	0	0.00016	2.828	0.107	0	3.9E-05	6.216	0.020	0	1.6E-05			35.176	0	0.00457	1445
1455	0	0.00013	1.719	0.881	0	0.0002	2.704	0.275	0	9.7E-05	5.977	0.076	0	5.9E-05			34.228	0	0.00445	1455
1465	0	0.00013	1.638	0.869	0	0.00019	2.586	0.156	0	5.2E-05	5.746	0.028	0	2.1E-05			33.301	0	0.00433	1465
1475	0	0.00013	1.562	0.938	0	0.00019	2.472	0.259	0	8.3E-05	5.523	0.057	0	4.1E-05			32.395	0	0.00421	1475
1485	0	0.00013	1.488	0.944	0	0.00018	2.363	0.224	0	6.9E-05	5.308	0.044	0	3.1E-05			31.509	0	0.0041	1485
1495	0	0.00013	1.418	0.977	0	0.00018	2.258	0.286	0	8.4E-05	5.101	0.060	0	4E-05			30.644	0	0.00398	1495
1505	0	0.0002	1.351	0.989	0	0.00027	2.158	0.413	0	0.00018	4.901	0.109	0	0.00011			29.798	0	0.00596	1505
1515	0	0.0002	1.286	0.990	0	0.00025	2.062	0.335	0	0.00014	4.708	0.077	0	7.3E-05			28.971	0	0.00579	1515
1525	0	0.0002	1.225	0.997	0	0.00024	1.970	0.421	0	0.00017	4.523	0.101	0	9.1E-05			28.164	0	0.00563	1525
1535	0	0.0002	1.167	0.998	0	0.00023	1.882	0.464	0	0.00017	4.344	0.104	0	9.1E-05			27.376	0	0.00548	1535
1545	0	0.0002	1.111	0.999	0	0.00022	1.797	0.467	0	0.00017	4.172	0.108	0	9E-05			26.607	0	0.00532	1545

1555	0	0.0002	1.058	1.000	0	0.00021	1.716	0.526	0	0.00018	4.006	0.132	0	0.00011			25.856	0	0.00517	1555
1565	0	0.0002	1.007	0.999	0	0.0002	1.639	0.412	0	0.00014	3.846	0.082	0	6.3E-05			25.123	0	0.00502	1565
1575	0	0.0002	0.9582	0.998	0	0.00019	1.565	0.352	0	0.00011	3.692	0.065	0	4.8E-05			24.408	0	0.00488	1575
1585	0	0.0002	0.9119	0.991	0	0.00018	1.494	0.245	0	7.3E-05	3.544	0.053	0	3.8E-05			23.711	0	0.00474	1585
1595	0	0.0002	0.8678	0.990	0	0.00017	1.426	0.302	0	8.6E-05	3.401	0.088	0	6E-05			23.030	0	0.00461	1595
1605	0	0.0002	0.8256	0.992	0	0.00016	1.361	0.352	0	9.6E-05	3.264	0.108	0	7E-05			22.367	0	0.00447	1605
1615	0	0.0002	0.7855	0.994	0	0.00016	1.299	0.377	0	9.8E-05	3.132	0.115	0	7.2E-05			21.720	0	0.00434	1615
1625	0	0.0002	0.7472	0.994	0	0.00015	1.239	0.429	0	0.00011	3.005	0.154	0	9.2E-05			21.090	0	0.00422	1625
1635	0	0.0002	0.7107	0.991	0	0.00014	1.182	0.424	0	0.0001	2.882	0.146	0	8.4E-05			20.475	0	0.00409	1635
1645	0	0.0002	0.6758	0.989	0	0.00013	1.128	0.359	0	8.1E-05	2.765	0.093	0	5.2E-05			19.876	0	0.00398	1645
1655	0	0.0002	0.6427	0.975	0	0.00013	1.076	0.369	0	7.9E-05	2.652	0.100	0	5.3E-05			19.293	0	0.00386	1655
1665	0	0.0002	0.6111	0.958	0	0.00012	1.026	0.276	0	5.7E-05	2.543	0.063	0	3.2E-05			18.724	0	0.00374	1665

1675	0	0.0002	0.5809	0.949	0	0.00011	0.9787	0.266	0	5.2E-05	2.438	0.064	0	3.1E-05		18.171	0	0.00363	1675		
1685	0	0.0002	0.5523	0.957	0	0.00011	0.9333	0.382	0	7.1E-05	2.338	0.102	0	4.8E-05		17.632	0	0.00353	1685		
1695	0	0.0002	0.5249	0.938	0	9.8E-05	0.8899	0.436	0	7.8E-05	2.241	0.131	0	5.9E-05		17.107	0	0.00342	1695		
1705	0	0.0002	0.4989	0.908	0	9.1E-05	0.8484	0.440	0	7.5E-05	2.148	0.146	0	6.3E-05		16.596	0	0.00332	1705		
1715	0	0.0003	0.4741	0.899	0	0.00013	0.8087	0.467	0	0.00011	2.059	0.154	0	9.5E-05		16.099	0	0.00483	1715		
1725	0	0.0003	0.4505	0.655	0	8.8E-05	0.7709	0.294	0	6.8E-05	1.974	0.097	0	5.7E-05		15.615	0	0.00468	1725		
1735	0	0.0003	0.4280	0.840	0	0.00011	0.7347	0.353	0	7.8E-05	1.891	0.130	0	7.4E-05		15.144	0	0.00454	1735		
1745	0	0.0003	0.4066	0.776	0	9.5E-05	0.7002	0.240	0	5E-05	1.812	0.082	0	4.5E-05		14.685	0	0.00441	1745		
1755	0	0.0003	0.3863	0.511	0	5.9E-05	0.6672	0.113	0	2.3E-05	1.736	0.031	0	1.6E-05		14.240	0	0.00427	1755		
1765	0	0.0003	0.3669	0.502	0	5.5E-05	0.6357	0.108	0	2.1E-05	1.663	0.030	0	1.5E-05		13.806	0	0.00414	1765		
1775	0	0.0003	0.3485	0.639	0	6.7E-05	0.6056	0.183	0	3.3E-05	1.593	0.049	0	2.3E-05		13.384	0	0.00402	1775		
1785	0	0.0003	0.3309	0.357	0	3.5E-05	0.5769	0.077	0	1.3E-05	1.526	0.024	0	1.1E-05		12.974	0	0.00389	1785		
1795	0	0.0003	0.3142	0.640	0	6E-05	0.5495	0.172	0	2.8E-05	1.462	0.049	0	2.1E-05		12.576	0	0.00377	1795		
1805	0	0.0003	0.2984	0.296	0	2.7E-05	0.5234	0.046	0	7.2E-06	1.400	0.013	0	5.6E-06		12.188	0	0.00366	1805		
1815	0	0.0003	0.2833	0.221	0	1.9E-05	0.4985	0.046	0	6.9E-06	1.340	0.014	0	5.6E-06		11.812	0	0.00354	1815		
1825	0	0.0003	0.2689	0.425	0	3.4E-05	0.4747	0.117	0	1.7E-05	1.283	0.036	0	1.4E-05		11.446	0	0.00343	1825		
1835	0	0.0003	0.2552	0.285	0	2.2E-05	0.4520	0.070	0	9.5E-06	1.229	0.024	0	8.7E-06		11.090	0	0.00333	1835		
1845	0	0.0003	0.2423	0.411	0	3E-05	0.4303	0.111	0	1.4E-05	1.176	0.038	0	1.3E-05		10.744	0	0.00322	1845		
1855	0	0.0003	0.2299	0.134	0	9.3E-06	0.4097	0.026	0	3.2E-06	1.126	0.009	0	3.2E-06		10.409	0	0.00312	1855		
1865	0	0.0003	0.2182	0.394	0	2.6E-05	0.3900	0.106	0	1.2E-05	1.078	0.031	0	1E-05		10.082	0	0.00302	1865		
1875	0	0.0003	0.2070	0.189	0	1.2E-05	0.3712	0.038	0	4.2E-06	1.031	0.008	0	2.5E-06		9.766	0	0.00293	1875		
1885	0	0.0003	0.1964	0.272	0	1.6E-05	0.3533	0.066	0	7E-06	0.9869	0.017	0	4.9E-06		9.458	0	0.00284	1885		
1895	0	0.0003	0.1864	0.258	0	1.4E-05	0.3362	0.057	0	5.7E-06	0.9443	0.018	0	5.1E-06		9.159	0	0.00275	1895		
1905	0	0.0003	0.1768	0.389	0	2.1E-05	0.3200	0.100	0	9.6E-06	0.9035	0.030	0	8E-06		8.869	0	0.00266	1905		

1915	0	0.0003	0.1677	0.480	0	2.4E-05	0.3044	0.121	0	1.1E-05	0.8644	0.032	0	8.3E-06			8.588	0	0.00258	1915
1925	0	0.0003	0.1591	0.353	0	1.7E-05	0.2897	0.084	0	7.3E-06	0.8270	0.022	0	5.6E-06			8.315	0	0.00249	1925
1935	0	0.0003	0.1508	0.348	0	1.6E-05	0.2756	0.125	0	1E-05	0.7911	0.035	0	8.4E-06			8.049	0	0.00241	1935
1945	0	0.0003	0.1431	0.220	0	9.4E-06	0.2622	0.053	0	4.1E-06	0.7566	0.015	0	3.5E-06			7.792	0	0.00234	1945
1955	0	0.0003	0.1357	0.120	0	4.9E-06	0.2494	0.026	0	1.9E-06	0.7237	0.007	0	1.6E-06			7.542	0	0.00226	1955
1965	0	0.0003	0.1286	0.170	0	6.5E-06	0.2372	0.039	0	2.8E-06	0.6921	0.012	0	2.5E-06			7.300	0	0.00219	1965
1975	0	0.0003	0.1220	0.046	0	1.7E-06	0.2256	0.016	0	1.1E-06	0.6618	0.006	0	1.2E-06			7.065	0	0.00212	1975
1985	0	0.0003	0.1156	0.059	0	2E-06	0.2145	0.026	0	1.7E-06	0.6328	0.010	0	1.9E-06			6.837	0	0.00205	1985
1995	0	0.0003	0.1096	0.143	0	4.7E-06	0.2040	0.054	0	3.3E-06	0.6050	0.020	0	3.6E-06			6.616	0	0.00198	1995
2005	0	0.0003	0.1039	0.089	0	2.8E-06	0.1940	0.054	0	3.2E-06	0.5784	0.021	0	3.7E-06			6.401	0	0.00192	2005
2015	0	0.0003	0.0985	0.197	0	5.8E-06	0.1844	0.103	0	5.7E-06	0.5530	0.040	0	6.6E-06			6.193	0	0.00186	2015
2025	0	0.0003	0.0933	0.225	0	6.3E-06	0.1753	0.124	0	6.5E-06	0.5286	0.047	0	7.4E-06			5.992	0	0.0018	2025

2035	0	0.0003	0.0884	0.362	0	9.6E-06	0.1667	0.191	0	9.5E-06	0.5053	0.070	0	1.1E-05			5.796	0	0.00174	2035			
2045	0	0.0003	0.0838	0.544	0	1.4E-05	0.1584	0.250	0	1.2E-05	0.4829	0.093	0	1.3E-05			5.606	0	0.00168	2045			
2055	0	0.0003	0.0794	0.772	0	1.8E-05	0.1506	0.340	0	1.5E-05	0.4615	0.122	0	1.7E-05			5.423	0	0.00163	2055			
2065	0	0.0003	0.0752	0.875	0	2E-05	0.1431	0.513	0	2.2E-05	0.4410	0.219	0	2.9E-05			5.245	0	0.00157	2065			
2075	0	0.0003	0.0713	0.918	0	2E-05	0.1360	0.679	0	2.8E-05	0.4214	0.331	0	4.2E-05			5.072	0	0.00152	2075			
2085	0	0.0003	0.0675	0.843	0	1.7E-05	0.1293	0.679	0	2.6E-05	0.4027	0.308	0	3.7E-05			4.905	0	0.00147	2085			
2095	0	0.0003	0.0640	0.860	0	1.7E-05	0.1228	0.773	0	2.8E-05	0.3847	0.400	0	4.6E-05			4.743	0	0.00142	2095			
2105	0	0.0003	0.0606	0.890	0	1.6E-05	0.1167	0.826	0	2.9E-05	0.3676	0.445	0	4.9E-05			4.586	0	0.00138	2105			
2115	0	0.0003	0.0574	0.812	0	1.4E-05	0.1109	0.682	0	2.3E-05	0.3511	0.349	0	3.7E-05			4.433	0	0.00133	2115			
2125	0	0.0003	0.0544	0.912	0	1.5E-05	0.1054	0.846	0	2.7E-05	0.3354	0.463	0	4.7E-05			4.286	0	0.00129	2125			
2135	0	0.0003	0.0515	0.428	0	6.6E-06	0.1001	0.267	0	8E-06	0.3204	0.125	0	1.2E-05			4.143	0	0.00124	2135			
Integrated radiances:				164.784	1.63908				226.342	1.3283			213.402	1.12939				2002.83	17.5021				
Requirement					1.64784					2.2634				2.13402					20.0283				
Margin ratio (>1 means OK)					1.0052					1.7040				1.88953					1.1443				
Height:			10 km				20 km				30 km						Black calibration target						

Notes:
1) for each height the two integrated radiances are the in-band and out-of-band respectively in units of mW/m**2/ster.
2) The requirement is the bigger of the NEN*0.5 and the in-band radiance *0.01.
3) The margin ratio is requirement/out-of-band radiance; hence values of 1 and larger indicate that the requirement is fulfilled.
In this case the requirement is unfulfilled (at all heights and for the black target), hence greater blocking is needed.