# Postlaunch Corrections for Thematic Mapper 5 (TM-5) Radiometry in the Thematic Mapper Image Processing System (TIPS)

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ABSTRACT: The paper discusses postlaunch corrections made to the calibration lamp radiance values for band 3 of TM-5 (Thematic Mapper instrument on Landsat-5). It is hypothesized that the low in-orbit temperatures have caused the shutter arm to contract slightly, causing the detectors to view the lamps through different parts of the lens system. Owing to unevenness in the lenses this is introducing an odd-even channel discrepancy in the computed gains, resulting in striped imagery. The process used to compute the new values is presented along with supporting data and the old and new radiance numbers. The new values solve the relative radiometric correction problem of striping. However, the effect on the absolute radiometric correction performance is not quantitatively known.

## INTRODUCTION

There are two types of radiometric corrections that are applied to sensor data from the Landsat instruments. These are normally referred to as relative and absolute radiometric corrections. The need for relative radiometric correction stems from the fact that there are multiple detectors (per band) for both the Thematic Mapper (TM) and the Multispectral Scanner (MSS) on Landsat. The detectors do not behave alike, and it is not possible to determine the relative variations between each precisely. The resultant imagery then appears striped. The purpose of relative radiometric correction is to eliminate or minimize the striping, and it utilizes techniques such as Scene Content Correction (histogram equalization) to achieve this end (Horn, 1979; Algazi, 1981).

Absolute radiometric correction, on the other hand, is done to ensure that the pixel values on the archival and product tapes correctly represent the reflected radiances observed by the sensor. It consists of two parts. The first part deals with calibrating the Internal Calibrator (IC) lamps by determining the radiances observed by each of the detectors for each of the calibration pulse states. This is done once before launch using the Integrating Sphere as the reference source. The TM sensors are used as a transfer instrument to calibrate the lamp radiances to the absolute radiances generated by the sphere (Barker, 1984). The second part of absolute radiometric correction is made in the Thematic Mapper Image Processing System (TIPS) during the regular processing of the data. It consists of computing the gains and biases for each channel by performing a regression between the lamp radiances (independent variable) and the in-flight calibration pulse values (dependent variable). It is implicitly assumed in this process that the IC is stable. The lamp radiances determined once, prior to launch of the satellite, do not change. Therefore, any change in the individual channel gains and biases are due to changes in the detectors.

As part of the Landsat Ground Segment verification, it was necessary to ensure that the radiometric corrections were being applied properly. This requirement for absolute radiometric correction was demonstrated by treating the TM-5 Integrating Sphere data as regular flight data and processing it through TIPS (Nastvogel, 1984a). NASA had specified a requirement of ten percent accuracy on absolute radiometry for the sensor (NASA, 1978). The requirement levied on the ground system correction was that it must not degrade the sensor performance. The results in Nastvogel (1984a) show that the radiometric correction is working as intended, and performance is well within requirements for both the sensors and the ground processing.

The performance for relative radiometric correction, on the other hand, is documented in Singh (1985) in this journal. The results presented there include the postlaunch corrections that had to be made to the IC lamp radiances and which are the subject of this paper.

### POSTLAUNCH CORRECTIONS TO BAND 3

Some change to the radiometry can be expected after launch under flight conditions. As mentioned

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above, this is assumed to be due to changes in the detectors and not because of changes in the IC system. However, for Landsat-5, patterns were noticed which could not be completely attributed to changes in the solid state detectors. For some bands, especially band 3, postlaunch gains between the odd and even channels differed by up to 20 percent. For regular data processing, part of the difference could be accommodated by the Scene Content Correction (SCC) process, which adjusts the gains to more similar values. However, scenes were still being generated with residual striping, and the absolute correction was also uncertain.

Table 1 shows the raw voltage counts, histogram means, and standard deviations for a typical scene. The fact that the odd-even channel pattern is not due to sensor gain changes is evident by examining these figures. If the pattern is sensor driven, these raw data statistics would also exhibit the odd-even channel differences. On the other hand, Table 2 shows the normalized calibration pulse values for the same scene. Here the pattern is evident. This suggests the problem lies with the viewing of the IC lamps by the detectors. Note that normalized here means a sum over 65 pixels centered around the pulse, divided by 65 and multiplied by 1.625. The 1.625 is an arbitrarily chosen form factor to estimate the "height" of the pulse. It has no effect on the actual correction, as the same factor was included in computing the lamp radiances originally. Its effect cancels out. However, some of the (arbitrarily defined) pulse heights for the brightest lamp state (state 111) come out greater than 255.

It is hypothesized that due to the thermal contraction of the shutter flag because of the lower in-orbit temperatures, the band 3 detectors are now viewing the calibration lamps through a slightly different part of the lens system than they did on the ground. The odd and even detectors lie on parallel axes orthogonal to the shutter and the thermal contraction direction. This shift is causing shading effects, perhaps due to unevenness of the lenses. Thus even though the IC performance may not have changed, the lamp radiances determined prior to launch are not valid. It was therefore decided to recompute effective radiances for band 3, to reflect flight conditions. The odd-even channel difference is also ob served for other bands, but is much less (3–5 percent), and these relative differences are easily corrected for by the histogram equalization process.

The first problem was to determine which of the odd or even channels gains were in error. Table 3 shows the (faulty) gains and biases for the same scene referred to in Tables 1 and 2. The odd-even channel differences can clearly be seen under the "Gains" column. The gains and biases shown here are the normalized gains and biases which relate the raw DN numbers to the quantized radiance or corrected DN values by the equation:

TABLE 1. RAW DATA HISTOGRAM MEANS AND STANDARD DEVIATIONS FOR BAND 3 CHANNELS. SCENE ID 5-0014-15452. UNITS ARE RAW DNs

| Detector | Mean | Std. Dev. |
|---|---|---|
| 1 | 39.683 | 13.552 |
| 2 | 39.736 | 13.817 |
| 3 | 39.111 | 13.588 |
| 4 | 39.237 | 13.743 |
| 5 | 39.116 | 13.628 |
| 6 | 38.694 | 13.433 |
| 7 | 38.555 | 13.399 |
| 8 | 39.068 | 13.522 |
| 9 | 38.783 | 13.422 |
| 10 | 39.103 | 13.635 |
| 11 | 38.750 | 13.503 |
| 12 | 39.257 | 13.741 |
| 13 | 38.782 | 13.581 |
| 14 | 39.164 | 13.676 |
| 15 | 39.116 | 13.602 |
| 16 | 39.503 | 13.719 |

$$Lq = G * Lr + B \qquad (1)$$

where $Lq$ is the corrected DN number or quantized radiance value, $Lr$ is the raw DN number, and $G$ and $B$ are the gains and bias for the channel. The quantized radiance range is such that 0 and 255 correspond to the $R_{min}$ and $R_{max}$ radiance values ($-0.008$ and $1.369\ mW/(cm^2 sr)$ for band 3). (Barker, 1985, Appendix 9.1). For a more detailed description of the radiometric correction process, see Singh (1985) in this journal or Singh (1983).

Table 4 shows corresponding normalized gains and biases for band 3, TM-5, determined using prelaunch Integrating Sphere data (Barker, 1985, Appendices 9.3 and 9.4). By comparing the two gain columns of Tables 3 and 4 it appears that the even channels are the ones in error. This fact is further substantiated by comparing the gains of TM-4 and TM-5 sensors for band 3, as the two are being corrected to the same $R_{min}$, $R_{max}$ range.

Table 5 shows the average corrected DN values for four corresponding ground areas, taken from the simultaneous overlap data of 15 and 16 March 1984 (Nastvogel, 1984b). That paper shows that over all the TIPS processing for the two sensors is consistent. In particular, band 3, TM-4 and TM-5 are within 6 percent, with TM-5 consistently less than TM-4. This last fact is understandable, as half the channel gains for TM-5 were being computed less than their counterparts for TM-4. The corrected TM-5 average values will therefore also be less. In any case it allows us to perform a comparison of the gains for band 3 for TM-4 and TM-5. Table 6 shows these gains for TM-4 band 3, for the corresponding overlap scene. These may be compared to the Table 3 figures. The comparison again indicates that the even channel gains are incorrect.

TABLE 2. NORMALIZED CALIBRATION PULSE VALUES FOR BAND 3 SHOWING DIFFERENCES BETWEEN ODD AND EVEN CHANNELS. SCENE ID 5-0014-15452. UNITS ARE RAW DNs

| Detector | Lamp State | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 100 | 110 | 010 | 011 | 111 | 101 | 001 | 000 |
| 1 | 108.17 | 188.01 | 85.19 | 152.65 | 255.25 | 175.39 | 72.23 | 4.86 |
| 2 | 98.35 | 177.16 | 83.23 | 151.91 | 245.45 | 166.80 | 72.71 | 3.86 |
| 3 | 107.44 | 187.27 | 84.47 | 152.06 | 254.75 | 174.80 | 71.55 | 4.17 |
| 4 | 97.47 | 175.78 | 82.44 | 150.77 | 244.04 | 165.51 | 72.04 | 3.67 |
| 5 | 107.72 | 188.12 | 84.74 | 152.77 | 256.04 | 175.46 | 71.88 | 3.89 |
| 6 | 95.86 | 172.88 | 81.19 | 148.25 | 239.98 | 162.79 | 70.82 | 3.76 |
| 7 | 106.26 | 185.57 | 83.65 | 150.70 | 252.62 | 173.16 | 70.91 | 3.87 |
| 8 | 96.39 | 173.74 | 81.61 | 148.94 | 241.06 | 163.58 | 71.34 | 3.82 |
| 9 | 106.58 | 186.11 | 83.97 | 151.26 | 253.31 | 173.71 | 71.31 | 4.06 |
| 10 | 96.42 | 174.05 | 81.71 | 149.34 | 241.62 | 163.93 | 71.46 | 3.73 |
| 11 | 106.55 | 186.16 | 83.89 | 151.36 | 253.53 | 173.84 | 71.24 | 3.88 |
| 12 | 96.97 | 175.07 | 82.17 | 150.25 | 243.11 | 164.89 | 71.84 | 3.75 |
| 13 | 106.86 | 186.86 | 84.05 | 151.90 | 254.52 | 174.45 | 71.37 | 3.63 |
| 14 | 96.72 | 174.53 | 81.97 | 149.84 | 242.37 | 164.41 | 71.77 | 3.74 |
| 15 | 107.42 | 187.68 | 84.49 | 152.56 | 255.62 | 175.34 | 71.74 | 3.66 |
| 16 | 97.67 | 176.33 | 82.75 | 151.47 | 244.99 | 166.21 | 72.58 | 3.83 |

Based on the above conclusion, a procedure was designed to compute new effective radiances for the IC lamps for band 3, using the odd channels as reference. The procedure is described below. By calibrating to the flight data for the odd channels, any band level shifts due to change in the environment after launch would be preserved.

The procedure used to recompute the band 3 radiances is similar in concept to the Scene Content Correction algorithm used to match the channels. Given a set of raw data histograms for a scene, and a reference corrected data (quantized radiance) histogram, the aim was to determine a gain and bias for each of the channels, that would generate the reference data histogram. Once a new set of gains and biases had been determined, the new radiances could be computed using the calibration pulse values.

To compute the new gains and biases, a data set had to be selected. The scene chosen was NASA Identification 5-0014-15452 (path 20, row 35), taken on 15 March 1984. This is one of the simultaneous overlap data scenes. Tables 1, 2, and 3 contain band 3 data extracted from this scene.

Channel 13 was the quietest odd channel for band 3 (J. L. Barker, NASA, personal communication,

TABLE 3. OLD BAND 3 GAINS AND BIASES SHOWING THE ODD-EVEN CHANNEL DIFFERENCES. SCENE ID 5-0014-15452

| Detector | Gain | Bias |
|---|---|---|
| 1 | 1.202 | −1.70 |
| 2 | 1.005 | −1.09 |
| 3 | 1.205 | −1.10 |
| 4 | 1.008 | −0.74 |
| 5 | 1.203 | −0.96 |
| 6 | 1.020 | −0.61 |
| 7 | 1.221 | −0.96 |
| 8 | 1.011 | −0.73 |
| 9 | 1.215 | −1.04 |
| 10 | 1.013 | −0.77 |
| 11 | 1.213 | −0.90 |
| 12 | 1.008 | −0.68 |
| 13 | 1.208 | −0.74 |
| 14 | 1.010 | −0.69 |
| 15 | 1.201 | −0.83 |
| 16 | 1.009 | −0.59 |

TABLE 4. PRELAUNCH BAND 3 GAINS AND BIASES SHOWING NO ODD-EVEN CHANNEL DIFFERENCES. DETERMINED FROM INTEGRATING SPHERE DATA

| Detector | Gain | Bias |
|---|---|---|
| 1 | 1.215 | −1.51 |
| 2 | 1.206 | −0.92 |
| 3 | 1.218 | −0.92 |
| 4 | 1.208 | −0.61 |
| 5 | 1.218 | −0.76 |
| 6 | 1.221 | −0.65 |
| 7 | 1.235 | −0.81 |
| 8 | 1.211 | −0.80 |
| 9 | 1.229 | −0.99 |
| 10 | 1.213 | −0.72 |
| 11 | 1.228 | −0.81 |
| 12 | 1.207 | −0.65 |
| 13 | 1.222 | −0.65 |
| 14 | 1.208 | −0.70 |
| 15 | 1.214 | −0.69 |
| 16 | 1.204 | −0.79 |

TABLE 5. COMPARISONS OF MEANS FOR BAND 3 FOR TM-4 AND TM-5 OVERLAP SCENES, EXPRESSED IN CORRECTED DNs. DIFF% IS [100.0 * (TM5 − TM4)/TM4]

| | Areas | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| TM-4 | 42.92 | 55.57 | 138.05 | 156.92 |
| TM-5 | 41.20 | 52.38 | 130.11 | 147.67 |
| Diff% | −4.0 | −5.7 | −5.8 | −5.9 |

1984) and its output quantized radiance histogram ($\mu = 46.108$ ql and $\sigma = 16.4073$ ql) was selected as a reference. The quantized radiance histogram was generated by relabeling each raw DN histogram bin by the channel 13 gain and bias shown in Table 3 and equation (1). The new gains and biases for all channels were determined by the following expressions:

$$G_d = \sigma/\sigma_d \qquad (2)$$

$$B_d = \mu - G_d * \mu_d \qquad (3)$$

where

$G(d)$ = New gain for channel $d$
$B(d)$ = New bias for channel $d$
$\mu_d$ = Mean of raw data histogram for channel $d$
$\sigma_d$ = Standard deviation of raw data histogram for channel $d$

The theory behind these expression is as follows: Let $Lr$ be the raw data value and $Lq$ the output (corrected DNs or quantized radiance) data value. Then,

$$Lq = G_d * Lr + B_d \quad \text{for channel } d$$
$$\mu = \mathrm{Avg}(Lq) = G_d * \mathrm{Avg}(Lr) + B_d$$
$$= G_d * \mu_d + B_d, \quad \text{as } \mu_d = \mathrm{Avg}(Lr)$$

TABLE 6. TM-4 BAND 3 GAINS AND BIASES FOR COMPARISON WITH TABLE 3. SCENE ID 4-0608-15404

| Detector | Gain | Bias |
|---|---|---|
| 1 | 1.236 | −1.83 |
| 2 | 1.253 | −0.79 |
| 3 | 1.256 | −1.34 |
| 4 | 1.261 | −0.75 |
| 5 | 1.254 | −0.93 |
| 6 | 1.245 | −0.87 |
| 7 | 1.256 | −0.77 |
| 8 | 1.260 | −0.75 |
| 9 | 1.248 | −0.65 |
| 10 | 1.257 | −0.54 |
| 11 | 1.258 | −0.39 |
| 12 | 1.248 | −0.40 |
| 13 | 1.244 | −0.58 |
| 14 | 1.250 | −0.86 |
| 15 | 1.235 | −0.73 |
| 16 | 1.266 | −0.63 |

TABLE 7. NEW BAND 3 GAINS AND BIASES COMPUTED USING THE RAW DATA HISTOGRAMS AND CHANNEL 13 REFERENCE OUTPUT RADIANCE HISTOGRAM. SCENE ID 5-0014-15452

| Detector | $G_d$ | $B_d$ |
|---|---|---|
| 1 | 1.211 | −1.94 |
| 2 | 1.188 | −1.08 |
| 3 | 1.208 | −1.12 |
| 4 | 1.194 | −0.74 |
| 5 | 1.204 | −0.99 |
| 6 | 1.221 | −1.15 |
| 7 | 1.224 | −1.10 |
| 8 | 1.213 | −1.30 |
| 9 | 1.222 | −1.30 |
| 10 | 1.203 | −0.94 |
| 11 | 1.215 | −0.98 |
| 12 | 1.194 | −0.77 |
| 13 | 1.208 | −0.75 |
| 14 | 1.200 | −0.88 |
| 15 | 1.206 | −1.07 |
| 16 | 1.196 | −1.14 |

Also,

$$\mathrm{Var}(Lq) = \sigma^2 = \mathrm{Avg}\{(Lq - \mu)^2\}$$
$$= G_d^2 * \mathrm{Var}(Lr)$$

So,

$$\sigma = G_d * \sigma_d, \qquad \text{as } \mathrm{Var}(Lr) = \sigma_d^2$$

Solving for $G_d$ and $B_d$ gives expressions (2) and (3). Table 7 shows the new gains and biases ($G_d$ and $B_d$) computed using the above algorithm. These were actually computed for all sixteen channels. The new values for the odd channels changed only slightly as expected.

Given the new gains and biases the next step was to transform them back to the uncalibrated range (with respect to $R_{min}$ and $R_{max}$). These are denoted as $G'_d$ and $B'_d$ and were computed by

$$G'_d = 255 \;/\; \{ (R_{max} - R_{min}) * G_d\}$$
$$B'_d = -\{R_{min} * 255 + B_d * (R_{max} - R_{min}) \} \;/\; G_d$$

where $R_{min} = -0.008$ and $R_{max} = 1.369\ mW/(cm^2 sd)$ for band 3. $G'$ and $B'$ are called the raw gains and biases. This is the reverse of the step performed during the computation of the normalized gains and biases in TAG (TM Archive Generation) (Singh, 1985). The new gains and biases relate absolute radiance $L$ to the raw detector voltage (DN) $Lr$ by the expression:

$$Lr = G'_d * L + B'_d$$

for channel $d$. Thus by substituting the normalized calibration pulse response for $Lr$ the new effective radiances of the lamps can be computed.

$$L_{dk} = [C_{dk} - B'_d] \;/\; G'_d$$

$C_{dk}$ are the normalized calibration pulse values for

TABLE 8. OLD (PRELAUNCH) CALIBRATION LAMP RADIANCES UNITS mW/(cm² sr)

| Detector | Lamp State | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 100 | 110 | 010 | 011 | 111 | 101 | 001 | 000 |
| 1 | 0.6866 | 1.2007 | 0.5308 | 0.9721 | 1.6400 | 1.1267 | 0.4554 | 0.0128 |
| 2 | 0.5310 | 0.9531 | 0.4352 | 0.7998 | 1.3154 | 0.8954 | 0.3756 | 0.0098 |
| 3 | 0.6861 | 1.2022 | 0.5307 | 0.9731 | 1.6431 | 1.1275 | 0.4551 | 0.0117 |
| 4 | 0.5295 | 0.9504 | 0.4343 | 0.7976 | 1.3133 | 0.8928 | 0.3748 | 0.0111 |
| 5 | 0.6879 | 1.2057 | 0.5324 | 0.9771 | 1.6496 | 1.1316 | 0.4569 | 0.0111 |
| 6 | 0.5282 | 0.9471 | 0.4332 | 0.7946 | 1.3076 | 0.8895 | 0.3734 | 0.0116 |
| 7 | 0.6892 | 1.2082 | 0.5334 | 0.9789 | 1.6525 | 1.1338 | 0.4577 | 0.0111 |
| 8 | 0.5257 | 0.9429 | 0.4314 | 0.7913 | 1.3016 | 0.8855 | 0.3720 | 0.0110 |
| 9 | 0.6880 | 1.2053 | 0.5325 | 0.9770 | 1.6485 | 1.1315 | 0.4574 | 0.0112 |
| 10 | 0.5269 | 0.9460 | 0.4326 | 0.7938 | 1.3066 | 0.8885 | 0.3730 | 0.0112 |
| 11 | 0.6866 | 1.2038 | 0.5316 | 0.9760 | 1.6470 | 1.1305 | 0.4567 | 0.0108 |
| 12 | 0.5276 | 0.9472 | 0.4330 | 0.7955 | 1.3088 | 0.8902 | 0.3740 | 0.0116 |
| 13 | 0.6867 | 1.2042 | 0.5314 | 0.9769 | 1.6483 | 1.1306 | 0.4570 | 0.0106 |
| 14 | 0.5270 | 0.9460 | 0.4329 | 0.7946 | 1.3070 | 0.8892 | 0.3741 | 0.0110 |
| 15 | 0.6859 | 1.2028 | 0.5308 | 0.9752 | 1.6457 | 1.1298 | 0.4563 | 0.0104 |
| 16 | 0.5323 | 0.9548 | 0.4367 | 0.8030 | 1.3202 | 0.8986 | 0.3786 | 0.0110 |

channel $d$ for lamp state $k$ as shown in Table 2. $L_{dk}$ are the new lamp radiances for band 3. The new radiances are listed in Table 9 and can be compared to the old radiances listed in Table 8. The lamp states are listed in sequence in which they occur in the TM instrument.

## SUMMARY

The in-orbit corrections to band 3 radiances were verified by examining scenes that were reprocessed with the new radiances, and by examining the photo products generated by the system for their radiometric correction quality. In all cases sensor striping was absent. Singh (1985) includes relative radiometric correction performance measures for TM-5 data processed with the new radiances.

The new lamp radiances for band 3 solve the relative radiometric correction problem of excessive striping. However, the absolute radiometric performance, which was verified with prelaunch data and parameters, is no longer known quantitatively. This applies to band 3 as well as other bands which demonstrated the odd-even channel discrepancies. It is therefore recommended that emphasis be given to postlaunch experiments for measuring that performance.

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TABLE 9. NEW (IN-ORBIT) CALIBRATION LAMP RADIANCES UNITS mW/(cm² sr)

| Detector | Lamp State | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 100 | 110 | 010 | 011 | 111 | 101 | 001 | 000 |
| 1 | 0.6887 | 1.2107 | 0.5385 | 0.9796 | 1.6503 | 1.1282 | 0.4538 | 0.0133 |
| 2 | 0.6169 | 1.1222 | 0.5199 | 0.9603 | 1.5601 | 1.0558 | 0.4524 | 0.0109 |
| 3 | 0.6865 | 1.2070 | 0.5368 | 0.9775 | 1.6471 | 1.1257 | 0.4525 | 0.0131 |
| 4 | 0.6164 | 1.1213 | 0.5195 | 0.9600 | 1.5613 | 1.0551 | 0.4525 | 0.0117 |
| 5 | 0.6870 | 1.2098 | 0.5376 | 0.9799 | 1.6513 | 1.1274 | 0.4540 | 0.0120 |
| 6 | 0.6180 | 1.1260 | 0.5212 | 0.9636 | 1.5685 | 1.0594 | 0.4529 | 0.0106 |
| 7 | 0.6887 | 1.2131 | 0.5391 | 0.9825 | 1.6564 | 1.1310 | 0.4549 | 0.0116 |
| 8 | 0.6166 | 1.1234 | 0.5198 | 0.9609 | 1.5645 | 1.0568 | 0.4524 | 0.0100 |
| 9 | 0.6885 | 1.2135 | 0.5397 | 0.9834 | 1.6571 | 1.1316 | 0.4557 | 0.0118 |
| 10 | 0.6134 | 1.1179 | 0.5178 | 0.9573 | 1.5569 | 1.0521 | 0.4512 | 0.0111 |
| 11 | 0.6859 | 1.2082 | 0.5372 | 0.9799 | 1.6503 | 1.1273 | 0.4541 | 0.0122 |
| 12 | 0.6131 | 1.1167 | 0.5177 | 0.9566 | 1.5553 | 1.0510 | 0.4511 | 0.0120 |
| 13 | 0.6851 | 1.2070 | 0.5363 | 0.9789 | 1.6485 | 1.1260 | 0.4536 | 0.0116 |
| 14 | 0.6138 | 1.1180 | 0.5183 | 0.9580 | 1.5574 | 1.0524 | 0.4522 | 0.0115 |
| 15 | 0.6859 | 1.2087 | 0.5365 | 0.9799 | 1.6512 | 1.1283 | 0.4535 | 0.0100 |
| 16 | 0.6166 | 1.1246 | 0.5203 | 0.9641 | 1.5680 | 1.0593 | 0.4546 | 0.0106 |

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