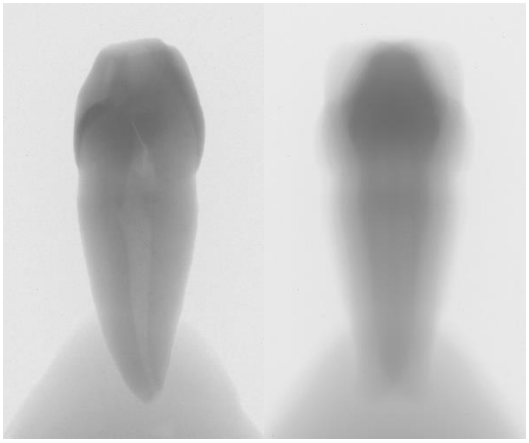
Partial ring artefact reduction

Method note

MCT-125

Enhanced partial ring artefact correction.

Ring artefact reduction in NRecon works by looking for invariant features in the "_arc.tif" image file, which is an average of all the scan projections. This corrects for rings present in most or all scan projections. However some ring features are present in only part of the rotation. By a small text edit to the scan log file, NRecon can be instructed to make multiple .arc files covering parts of the scan rotation – like slices of a cake. This is called partial ring artefact reduction, and it often greatly improves the removal of rings without the need to use a very large ring reduction value (large values sometimes cause new added artefacts).



(a) (b)

Figure 1. A scan projection image (a) and the arc file (b) averaged from all scan projections.

How do we do this? By adding to the scan log file (in acquisition part before "reconstruction") the line "FF updating interval=x" where x is the number of scan projections divided by a number "n" and rounded upwards to the next higher integer (not the nearest integer) if the result of the division is a number with digits after the decimal point. n is a number between 2-10. Thus,

$$x = \frac{number\ of\ projections}{n}$$

Generally *n* should be about 4-5 for scans with less projections (lower resolution) and at the high end (7-10) for scans with a larger number of projections. You need to choose this number yourself.

While the default "arc" file is an average of all projections, the partial ring correction maps are averages of *x* projection images (see figure 2 below).

Example of partial ring correction by editing the log file

Here is the log file from the scan of a canine tooth, in the SkyScan 1173 scanner. (This method can be applied to scans with any scanner.)

```
1  [System]
2  Scanner=SkyScan1173
3  Instrument S/N=001
4  Hardware version=A
5  Software=Version 1. 6 (build 10)
6  Home directory=C:\SkyScan1173
7  Source Type=Hamamatsu 130/300
8  Camera=FlatPanel Sensor
9  Camera Pixel Size (um)=50.0
10 CameraXYRatio=1.0020
11 Incl.in lifting (um/mm)=0.0000
12 [Acquisition]
13 Data directory=C:\Results\advanced training\tooth
14 Filename Prefix=tooth_
15 Number of Files=  720
16 Source Voltage (kV)=  80
17 Source Current (uA)= 100
18 Number of Rows= 1120
19 Number of Columns=  672
```

Line 15 tells us that the number of projections is 720.

We can choose for example to make 7 partial ring correction files (*n* = 7).

Now 720 / 7 = 102.8571

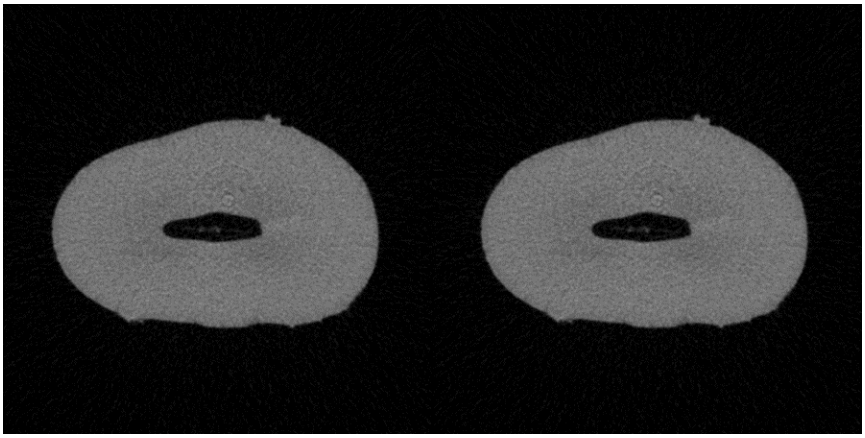
We round this number upwards to 103 (so now *x* = 103).

Please note – even if the decimal is less than 0.5, for instance 102.001, we will still round the number **upwards** e.g. to 103. This is important to avoid creating a thin final partial ring artefact map made from very few excess images. (Who wants a thin slice of cake??)

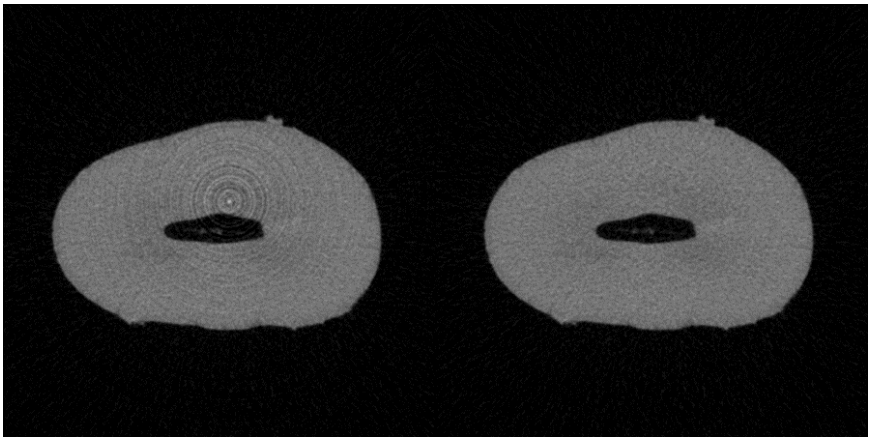
Now we edit into the log file this additional line: "FF updating interval=103"

```
35 Exposure (ms)=   700
36 Rotation Step (deg)=0.500
37 Frame Averaging=ON (2)
38 Random Movement=ON (20)
39 Use 360 Rotation=YES
40 FF updating interval=103
41 Geometrical Correction=OFF
42 Camera Offset=OFF
43 Median Filtering=OFF
44 Flat Field Correction=ON
45 Rotation Direction=CC
46 Scanning Trajectory=ROUND
47 Type Of Motion=STEP AND SHOOT
48 Study Date and Time=Dec 04, 2012  12:56:52
49 Scan duration=00:33:20
50 Maximum vertical TS=5.0
51 [Reconstruction]
```

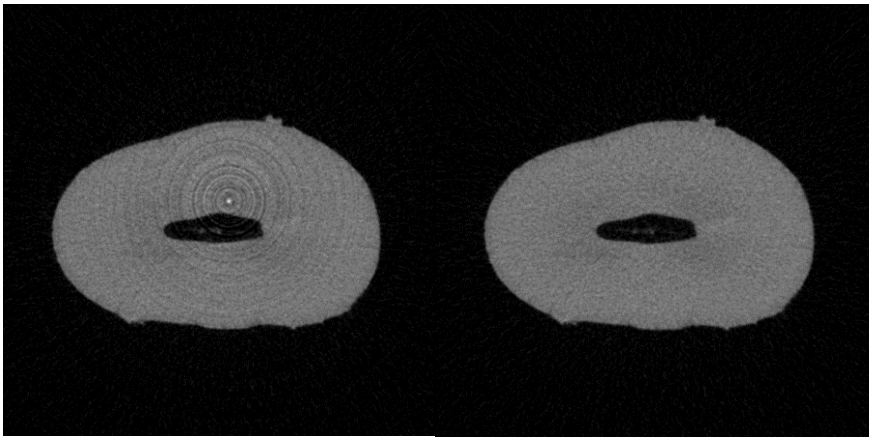
This new added line can be seen further down in the log file in line 40. Note that this line is not always present in the log file after scanning, depending on the model of scanner. If the line is missing, it should be added, at any location in the early part of the log file under the heading "Acquisition", from line 12 to about line 50. (For example, just under the line "Use 360 Rotation=YES/NO".) The number that we enter for FF updating is the one calculated by the method described above (the number "*x*").



Standard ring reduction, radius=0 Partial (n=7) ring reduction, radius=0



Standard ring reduction, radius=2 Partial (n=7) ring reduction radius=2



Standard ring reduction, radius=5 Partial (n=7) ring reduction radius=5

Figure 2. In datasets where standard ring reduction does not work well, partial ring reduction can improve the result, as in the case of this tooth.

After editing the scan log file in this way, reload the projection dataset. NRecon will then create the partial ring reduction files the next time that a preview reconstruction (or full reconstruction) is run.

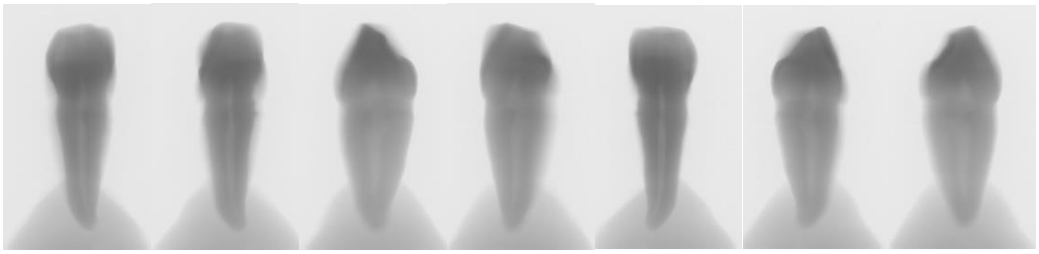
Figure 2 above shows the image results obtained by reconstruction either with standard and partial (n=7) ring reduction.

From the above images it can be seen that:

- With zero ring reduction there are minor ring artefacts
- With standard ring reduction with a single ring artefact map, increasing radius to 2 or 5 makes rings worse, not better
- With partial ring reduction using 7 ring artefact maps, increasing ring artefact reduction radius to 2 pixels removes the ring artefacts.

Ring reduction with and without this partial ring reduction method will not always show this pattern. However it frequently improves the effectiveness of ring artefact reduction.

A set of partial ring reduction image maps is shown in figure 2.

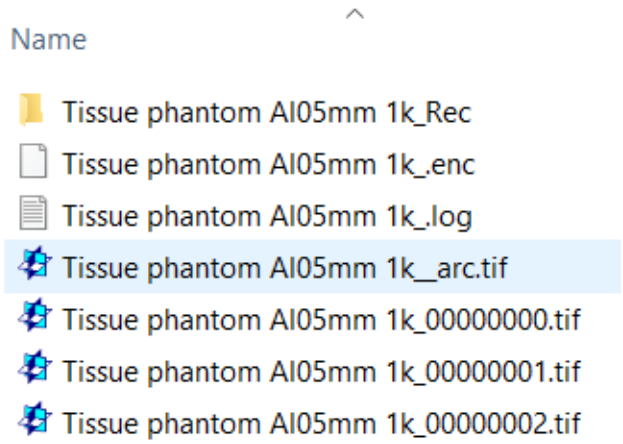


ar0 ar1 ar2 ar3 ar4 ar5 ar6

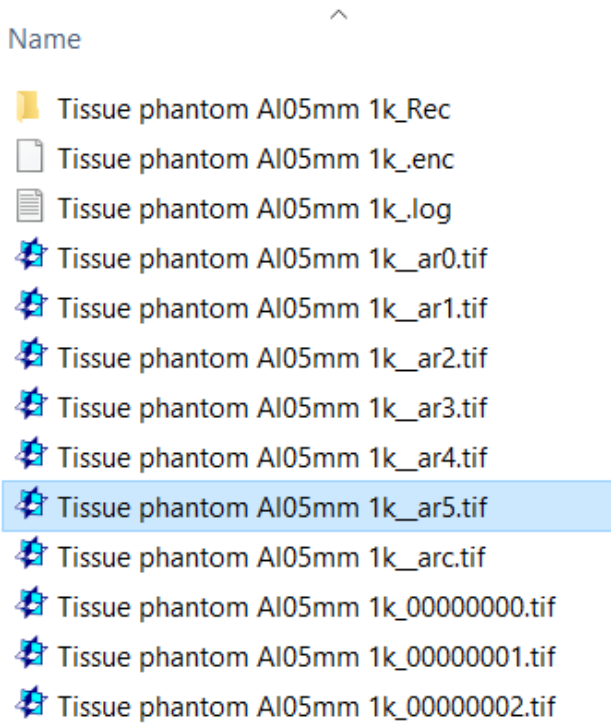
Figure 2. A set of partial ring reduction image maps.

Naming of the "arc" files in partial ring artefact correction

In any projection dataset from a SkyScan microCT scanner, a file with the name "scan-name_arc.tif" can be found among the tif projection images.



When the log file is edited as described above in section 2, the projection dataset should then be reloaded into NRecon. Once reloaded, on the first preview reconstruction the partial ring reduction files will be created. These files are given the filenames "_ar0.tif, _ar1.tif, _ar2.tif etc." The projection dataset will then look like the image below in the case that the chosen number of partial ring reduction files is six.



Final comments

Some SkyScan scanners automatically create partial ring correction files as described above, such as models 1272, 1275 and 1278. You may choose to experiment with changing the number of partial ring correction maps, by changing the number *x*.

If you would like to change the number of partial ring reduction image files, then first you need to delete the existing partial image files (_ar0, _ar1, etc.) from the projection dataset. If the scan is an oversize scan then this needs to be done for each scan part. This deleting is necessary for the new partial image files to be correctly made. Once the old partial ring correction files have been deleted, then edit the log file to change the number of images (*x*) to be averaged in each ring correction file:

FF updating interval = *(new number)*

Then reload the dataset into NRecon, and evaluate the reconstruction results with the new number of partial ring artefact reduction files.