



S-1 Mission Performance Centre

Masking "No-value" Pixels on GRD Products generated by the Sentinel-1 ESA IPF

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Applicable documents

- AD- 1 *S-1 Product Definition, S1-RS-MDA-52-7440
- AD- 2 *S-1 Product format specification, S1-RS-MDA-52-7441
- AD- 3 TOPSAR: Terrain Observation by Progressive, De Zan, F., & Guarnieri, A. M., Geoscience and Remote Sensing, IEEE Transactions on, 2006 vol. 44(9), pp.2352-2360.
- AD- 4 *Sentinel-1 SAR Performance Analysis, S1-TN-ARE-PL-0001, issue 1.7,01/03/2013
- AD- 5 *Sentinel-1 Level 1 Detailed Algorithm Definition, S1-TN-MDA-52-7445

(*) Latest version of the document is available on the S-1 product handbook web pages: <https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar/document-library>

Reference documents

None



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1. Introduction

The Sentinel-1 (S-1) Instrument Processing Facility (IPF) is responsible for generating the complete family of Level-1 and Level-2 operation products [AD- 1]. The processing of the RAW data into L1 [AD- 5] products features number of processing steps that may lead to artefacts at the image borders for products processed with IPF before IPF 2.90.

These processing steps are mainly the azimuth and /range compression and the sampling start time changes handling that is necessary to compensate for the change of earth curvature.

The latter is generating a number of leading and trailing "no-value" samples that depends on the data-take length that can be of several minutes. The former creates radiometric artefacts complicating the detection of the "no-value" samples.

The masking of the "no-value" pixel is easy using the SLC products as dedicated information is provided for each burst. However, for GRD products the masking is not straightforward.

This technical note describes an approach for masking the "no-pixel" values for GRD products. Three different approaches are proposed in this document:

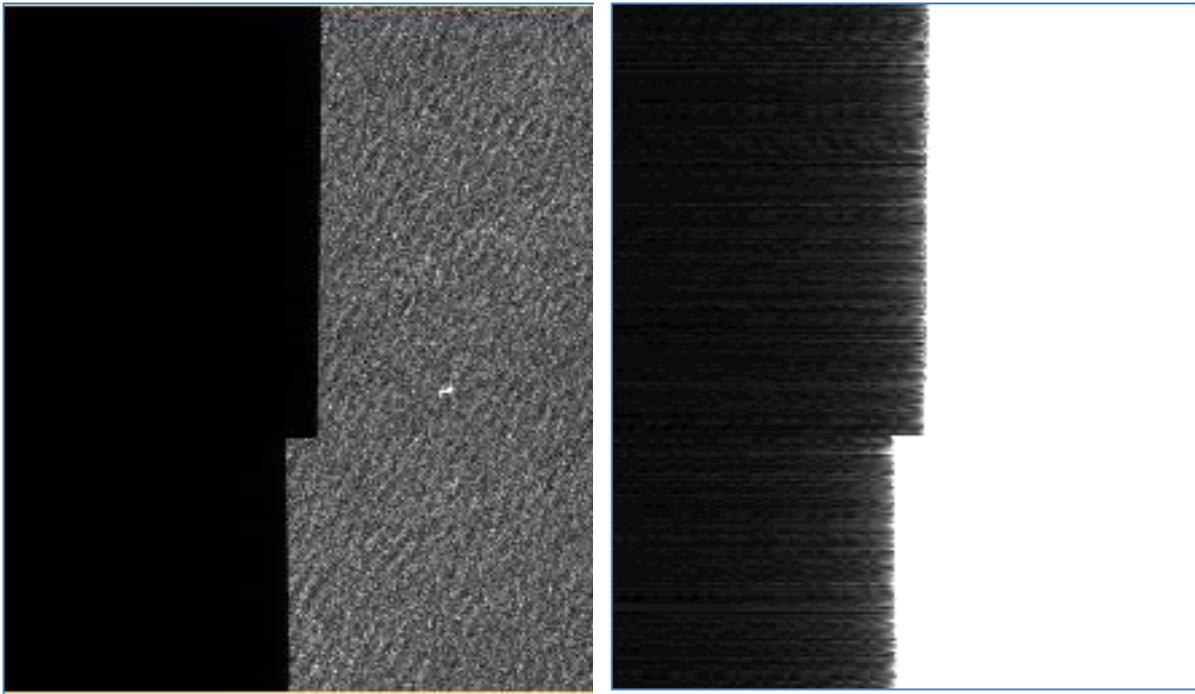
- For data processed with IPF 2.90 (and newer version): no specific masking is required
- For data processed with IPF version higher than 2.50 and up to IPF 2.84, an approach that relies on the usage of the denoising vectors. Those denoising vector are considered valid only starting from the IPF version higher than 2.50.
- For data processed with the earlier version an update approach is provided in section 4.6.

2. Problem description

The handling of the Sampling Window Start Time changes is creating an azimuth varying amount of black leading and trailing samples as can be observed in Figure 1.a. The amount of padding is dependent on the full data-take length that can be of several minutes. These samples are considered as "no-value" pixels.

With S-1, the SWST handling requires to resample the data as the changes are not integer of pixel (as it was on previous missions like ERS and ASAR). This resampling step with the other compression steps are making such that the "no-value" pixels are not null but contain very low values as shown in Figure 1.b. For GRD products, this effect seems to appear only at near range (and never at far range).

These "dirty" pixels are complicating the masking based on thresholding. This technical note proposes an approach allowing improving the efficiency of the thresholding method.



(a) block of IW GRDH data at near range exhibiting a SWST change

(a) same block of data saturating the data for putting in evidence the 'dirty' pixels

Figure 1: Dirty pixels at near range



3. Checking IPF version

As above mentioned, it is important to check the IPF version before applying the method described in section 0.

The IPF version is annotated in the manifest file (*manifest.safe*) as following:

```
<metadataObject ID="processing" classification="PROVENANCE" category="PDI">
<metadataWrap mimeType="text/xml" vocabularyName="SAFE" textInfo="Processing">
  <xmlData>
    <safe:processing name="SLC Post Processing" start="2017-05-29T19:23:31.979529" stop="2017-05-
29T19:32:31.000000">
      <safe:facility country="United Kingdom" name="Copernicus S1 Core Ground Segment - UPA" organisation="ESA"
site="Airbus DS-Newport">
        <safe:software name="Sentinel-1 IPF" version="002.82"/>
      </safe:facility>
    </safe:processing>
  </xmlData>
</metadataWrap>
...

```

4. Masking approach for IPF version 2.90 and higher

Starting with IPF 2.90, the no-value pixels at image borders are set to 0 value by the IPF. The masking of the borders thus does not require specific processing. Masking approach for IPF version lower than 2.90

The proposed approach consists in using the denoising vectors on the co-polarisation channel (HH or VV) in order to set the "dirty" pixels to zero easing their masking.

The mask detected on the co-polarisation data could similarly be applied on the cross-polarised channel [HV or VH] without recomputing it.

It is proposed to use the co-polarisation channel, as the level of signal is always better than the cross-polarisation. As matter of fact, under certain circumstances (e.g. sea, low wind speed) valid pixel in the cross-polarisation channel could be wrongly masked.

4.1. Denoising vectors

The noise vectors are provided in the *annotation/calibration* folder in the *noise-*.xml* file. In this document they are referred as *Noise Annotation Data Set NADS*.

As usual with the S-1 products, there are as many noise XML files as there are measurement TIFF files. The number of TIFF files depends on the product type and on the polarisation configuration, for:

- SLC: Number Sub-swath x Number of polarisation
- GRD: simply the number of polarisation (as the sub-swaths are merged in the case of TOPS)

The L1 Annotation Data Set (LADS) is the located in the main annotation folder.

There exact path can be retrieved from the product manifest.safe file contained in the product directory. Below is an example of reference to one of the noise annotation referenced by the manifest.

```
<dataObject ID="noises1aiwgrdv20150529t16431120150529t164531006138007f86001" repID="s1Level1NoiseSchema">
  <byteStream mimeType="text/xml" size="453360">
    <fileLocation locatorType="URL" href="./annotation/calibration/noise-s1a-iw-grd-vv-20150529t164311-
20150529t164531-006138-007f86-001.xml"/>
    <checksum checksumName="MD5">f205c02f09be8b6255bf8e0a92f7d6e0</checksum>
  </byteStream>
</dataObject>

```



The Calibration Annotation Data Set (CADS) are provided next to the NADS. For example:

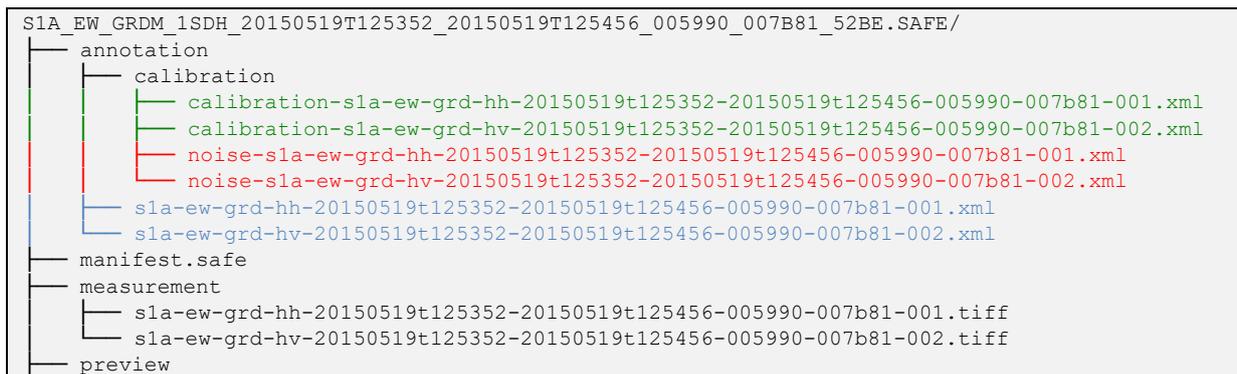


Figure 2: Representation of the product folder tree, with in red the NADS, in blue the LADS and in green the CADS

The noise vectors in the NADS are provided as a list of records (`noiseVectorList`) that are regularly updated in azimuth time to accommodate for the platform roll steering. Each record of the list (`noiseVector`) provides a (`noiseLut`) that contains the thermal noise as a function of the pixel index (`pixel`).

```
...
<noiseVectorList count="25">
  <noiseVector>
    <azimuthTime>2015-03-11T07:39:27.860692</azimuthTime>
    <line>1268</line>
    <pixel count="210">0 40 80 ... 8330</pixel>
    <noiseLut count="210">7.664914e+03 ... 7.603582e+03</noiseLut>
  </noiseVector>
...

```

The vector is sub-sampled with typically a step of 40 samples. Interpolation is thus required to get a value per sample.

Updates along azimuth are required for considering the platform roll steering law that is changing the off-boresight angle as function of latitude consequently changing the (elevation) antenna gain seen by samples belonging to the same azimuth line. However, **for the sake of masking "dirty" samples, the mid-noise vector can be used for all the slice.**

The approach proposed assumes that the noise vectors are properly scaled which is not the case with IPF version earlier than the 2.50. For data processed with earlier IPF version please consult section 4.6.

4.2. Step 1: Selecting the noise ADS

For GRD product there are at maximum two TIFF files and consequently two noise, calibration and annotations XML files i.e. one for each tiff.

The Sentinel-1 IPF is numbering the channel with channel ID starting at 1. The channel ID should always be the co-polarisation channel. However, it is proposed to select the channel based on the elements of the filename. As per [AD- 2], the data set naming containing the polarisation coded in two characters. Being the transmit (1st character) and receive (2nd character) polarisation configuration.

The co-polarisation channel is the one where transmit = receive. It can either be VV or HH. In the example below the co-polarisation channel is highlighted.



```
noise-sla-ew-grd-hh-20150519t125352-20150519t125456-005990-007b81-001.xml
noise-sla-ew-grd-hv-20150519t125352-20150519t125456-005990-007b81-002.xml
```

4.3. Step 2: Reading the noise vector

For IW products there are in general 25-27 noise vectors depending on the slice length. The number of vectors is provided by the **count** attribute of the **noiseVectorList** element.

As previously mentioned, for the sake of masking "dirty" pixels the mid record can be used.

```
noiseVectorNo = {count attribute of noiseVectorList}
noiseRecord = get_noiseRecord(noiseVectorNo/2)
```

noiseRecord is a structure matching the content of a NADS record:

```
noiseRecord{
  azimuthTime      DOUBLE
  line             LONG
  pixel            LONG      Array[NoiseLutLen]
  noiseLut         FLOAT     Array[NoiseLutLen]
}
```

noiseLutLen is the length of the sub-sampled vector given by the **count** attribute of the **noiseLut** element.

4.4. Step 3: Denoising at near range

Select the Measurement Data Set (MDS) related to the co-polarisation channel using similar approach as in step1. MDS are TIFF files located in the measurement folder.

It can be either VV or HH. In the example below the co-polarisation channel is highlighted.

```
sla-ew-grd-hh-20150519t125352-20150519t125456-005990-007b81-001.tiff
sla-ew-grd-hv-20150519t125352-20150519t125456-005990-007b81-002.tiff
```

```
mdsFile = sla-ew-grd-hh-20150519t125352-20150519t125456-005990-007b81-001.tiff

numberOfSamples : number of samples read from the TIFF header
numberOfLines: number of lines read from the TIFF header
```

Read the first 2000 samples of all lines. 2000 samples are enough to include all the no-value pixels. This corresponds to the portion of data in the red block in Figure 3.

```
nearRangeBlock = read_tiff(mdsFile, sub_rect=[0,0,2000, numberOfLines-1])
```

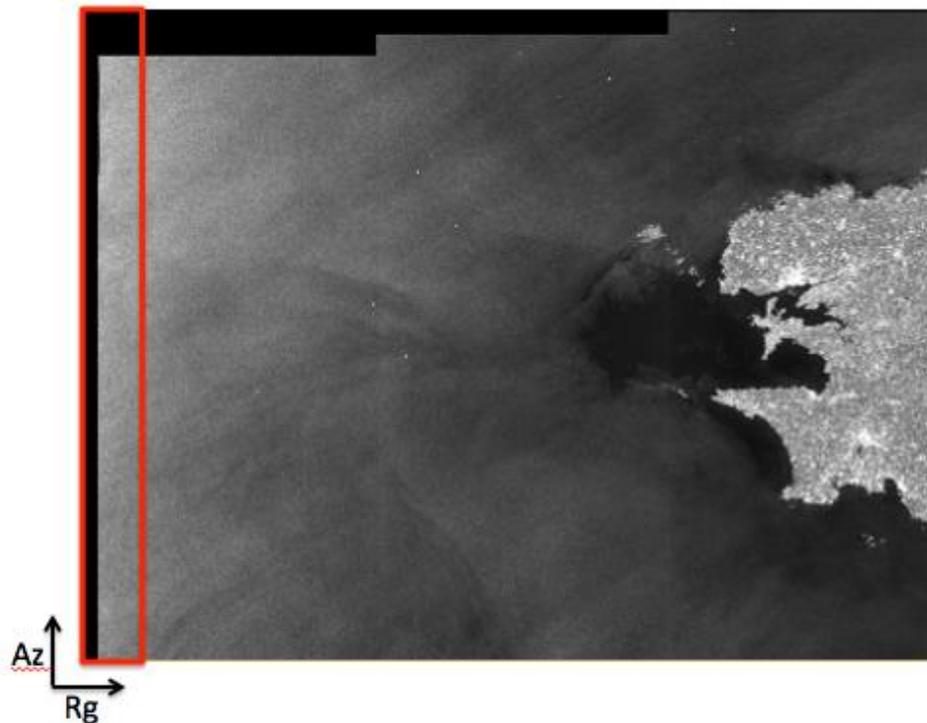


Figure 3: S-1 imagery exhibiting leading and trailing black samples at near and far range

Interpolate the noise vector for the first 2000 samples:

```
noiseLutInterpolated = interpol(noiseRec.noiseLut, noiseRec.pixel, indgen(2000))
```

Denoise the block of data according to the denoising procedure defined in [AD- 2]:

```
denoisedBlock = fltarr(2000, numberOfLines)
for l =0, numberOfLines-1 do begin
    ;perform denoising ensuring that negative values are clipped to 0.
    denoisedBlock(*,l) = (nearRangeBlock^2. - noiseLutInterpolated) >0
endfor
; go back to amplitude
denoisedBlock = sqrt(denoisedBlock)
```

4.5. Step 4: Masking at near range

After the denoising the "no-value pixels" are clipped to zero. The masking becomes a simple thresholding process.

```
trimTresh = 0.5
```



```

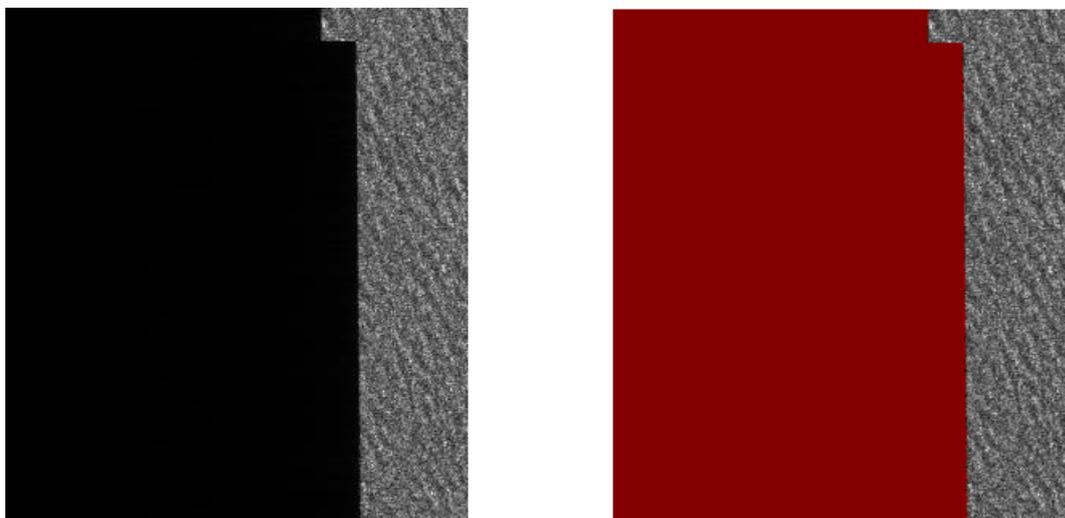
for l=0, numberOfLines-1 do begin
  trimNear = 0
  trimFar = 2000-1

  line = denoisedBlock(*,l)

  while (line[trimNear] lt trimTresh and trimNear lt trimFar) do trimNear++

  maskLine(0:trimNear,l) = 255
endfor

```



(a) original data block first 500 samples (b) red are the pixel masked by the above approach

Figure 4: Masking result

4.6. Masking data processed with IPF version lower than 2.50

The noise vectors provided with IPF version < 2.50 are not properly scaled. In order to use the approach described in this technical note, it is necessary to scale the vectors with the following values:

IW: 75088.7

EW: 56065.87

Read the IPF version from the manifest file (*manifest.safe*) file provided in the root of the product folder tree¹:

```

...
<facility country="Italy" name="ESRIN headquarters" organisation="ESRIN" site="Rome">
<software name="Sentinel-1 IPF" version="002.36"/>
</facility>

```

¹ This applies to the version of S-1 IPF operated by the Payload Data Ground Segment PDGS (Core Segment of the Sentinel-1 mission). Alternate versions of the processors can also be used for instance as part of the network of collaborative stations. At the date of preparation of this technical note the Collaborative S-1 IPF uses version numbers aligned with the one of the PDGS.



...

The denoising step 3 can be modified and made generic as following:

```
Case of mode:
'IW' : knoise = 75088.7
'EW' : knoise = 56065.87
default : knoise=1
endcase
```

Read the Digital Number LUT provided in the CADS related to the co-polarisation channel. The DN LUT is always the same and thus it is enough to read the first record:

```
;read the first CADS record
calibrationRecord = get_calibrationRecord(0)
```

calibrationRecord is a structure matching the content of a CADS record:

```
calibrationRecord{
  azimuthTime    DOUBLE
  line           LONG
  pixel          LONG      Array[calLutLen]
  sigmaNought   FLOAT     Array[calLutLen]
  betaNought     FLOAT     Array[calLutLen]
  gamma         FLOAT     Array[calLutLen]
  dn            FLOAT     Array[calLutLen]
}

;get the first element of the dn LUT
Adn = calibrationRecord.dn[0]
```

calLutLen is the length of the sub-sampled vector given by the **count** attribute of the **dn** array.

Perform the denoising:

```
denoisedBlock = fltarr(2000, numberOfLines)

for l =0, numberOfLines-1 do begin

  ;perform denoising ensuring that negative values are clipped to 0.
  denoisedBlock(*,l) = (nearRangeBlock^2. -
    noiseLutInterpolated*knoise*Adn^2.) >0

endfor

; go back to amplitude
denoisedBlock = sqrt(denoisedBlock)
```

After this step, the masking as done in step 4 can be applied.

4.7. Limitations

This approach is effective over land where the data acquired has a level of signal always higher than the instrument noise floor.



Over water body areas the level signal might be extremely low hence reaching the noise floor such that the denoising will theoretically clip most of the valid pixels to zero. This impacts most predominantly the cross-polarisation and it is mitigated by the usage of the co-polarisation in this technical note.

However, even for the co-polarisation over very low wind speed condition there might be no signal coming back to the radar thus also reaching the noise floor. In this situation, the masking approach based on only the denoising might not be sufficient, as most of the pixels will be masked.

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**Appendix A - List of acronyms**

| | |
|-------------|---------------------------------|
| CADS | Calibration Annotation Data Set |
| DN | Digital Number |
| EW | Extra Wide Swath |
| GRD | Ground Range Detected |
| IPF | Instrument Processing Facility |
| IW | Interferometric Wide Swath |
| LADS | Level 1 Annotation Data Set |
| LUT | Look Up Table |
| MPC | Mission Performance Centre |
| NADS | Noise Annotation Data Set |
| S-1 | Sentinel-1 |
| SLC | Single Look Complex |