TITLE: **QPATCH – An IDL Module to Simulate Signal Quantization on Sky Patches**

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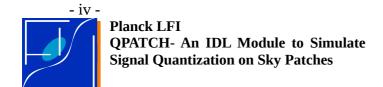Document No.:   PL-LFI-OAT-TN-020
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CHANGE RECORD

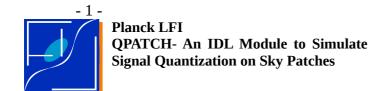| Issue	Date	Sheet	Description of Change	Release

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1   SCOPE

This document describes QPATCH a simulation tool to simulate signal quantization over a map or patch of sky without to perform a full simulation of the scan of the sky, i.e. avoinding the generation of a TOD followed by map making.

The main reason to develop this tool is to give a simple way to evaluate the quantization impact on component separation.

1.1   LIMITS OF APPLICABILITY

Basic hypotheses of the present release of QPATCH are:
1.   Just one quantization step is performed
2.   Noise is stationary
3.   Quantization properties are stationary

This introduces limitations:
1.   1/f noise and the destriping process can not be introduced easily
2.   The first quantization effect as the onboard processing is not fully accounted for.
3.   Variations in the calibration of the quantization step q are not accounted for.
4.   The number of quantized samples entering a pixel is exactly integer .

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2   APPLICABLE/REFERENCE DOCUMENTS

2.1   APPLICABLE DOCUMENTS

[1] *Quantization Errors on Simulated LFI Signals*,
    M. Maris, D. Maino, M. Bersanelli, C. Burigana, D. Mennella, F. Pasian
    2000-07-12, PL-LFI-OAT-TN-011
[2] *Statistics of a σ/q ~ 2 Data Stream from Planck/LFI*
    M. Maris
    2001-06-12, PL-LFI-OAT-TN-18

2.2   REFERENCE DOCUMENTS

[3] *On Board Processing, Compression and Telemetry Rate*
    Bersanelli et al., (2000),
    Issue #3, April 21, 2000
[4] Kollár I., (1994), IEEE Trans. Instr. Meas., **43**, 733
[5] *Data Streams from the Low Frequency Instrument On-Board the Planck Satellite: Statistical Analysis and Compression Efficiency*,
    Maris M., Maino D., Burigana C., Pasian F., (2000),
    astro-ph/0005101, accepted for publication in A&ASS

2.3   ACRONYMS LIST

ADU	Analog Digital Unit

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3 CODE DESCRIPTION

In the present release the code is composed of a driver `drive_ qpatch.pro` and a single routine `qpatch.pro` which accepts in input a map *tmap*, generates noise, then the quantized and the reconstructed map.

The quantized map is generated as specified in the following metacode:

> For each pixel in the *tmap*
> > N samples of white noise are generated
> > For each noise sample
> > > The given noise sample is added to the given map pixel
> > > The map pixel is quantized and stored
> > The arithmetic mean of the N quantized samples is computed

This process reproduces the two basic features for

The quantization process is performed according to the formula:

$$qt = \text{floor}[(t - tmin)/q]$$

where floor[x] is the floor operator which rounds *x* to the bigger integer *I* for which $I \leq x$. While *tmin* is the minimum value accepted for the input signal, *q* is the quantization step.

Further constraints are:

> if $(t < tmin)$ then $qt = 0$
> if $(t > tmax)$ then $qt = \text{floor}(tmax/q)$

where *tmin* and *tmax* are the minimum and maximum signal accepted by the quantization process.

The output of the quantization process is expressed in ADU (Analog/Digital Units), 1 ADU = 1*q. The nominal *q* for Planck, according to ESA requirements, is *σ/q ~ 2*. Tested values have been: *σ/q ~ 4, 2, 1, 1/2*. So the quantization step has to be tuned accordingly to the noise r.m.s. expected for the given radiometer and the *σ/q* of choice.

Note how in this scheme the computation of the average is not followed by any truncation to reduce the real number so far generated to an integer. The reason being the fact that such average is not performed on board but on the ground segment.

In a mission like Planck, the number of averages per pixel in the map is not a constant. In the simplest case the number of samples varies as the sine of the colatitude of the pixel. The present version of the code accepts two rules to fix the number of samples per pixel:

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1. constant number,
2. Number specified pixel by pixel through an external map.

A typical number of averages for Planck is $N = 60$. But other N shall be considered.

The reconstruction process transforms quantized quantities in physical quantities given q, *tmin*, it is simply described by the formula:

$$rqt = (qt + ½) * q + tmin,$$

note the ½ offset due to the use of the floor[x] quantization function, as noted in [1] if round[x] is used instead the offset has to be set to zero.

Note how the reconstruction process is performed *after* the averaging instead of *before*. In the hypothesis that averaging generates real numbers instead of integers the two schemes are equivalent but time is saved.

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4   PERFORMANCES AND COMMENTS

On a Ultra/SPARK work station a map of … samples is quantized for N = 60 in … sec.

The use of IDL make the program quite slow, however since the limited scopes of this code the velocity is acceptable. If required, a future release of `qpatch.pro` in F90 may be considered.

APPENDIX A   QPATCH

This section contains the listing of `qpatch.pro`

```
pro qpatch,rqmap,qmap,tmap,n,q,sigma,tmin,tmax
;
; IDL routine to generate quantized maps
;
; performs just the second quantization plus reconstruction
; assumes the use of floor
;
; rqmap = reconstructed map after quantization (float)
; qmap  = quantized map (float)
; tmap  = unquantized input map without noise (float)
; n     = number of repetitions of the quantization process (integer)
;         if N is a number the same number of repetitions is applied to all the
samples of the map
;         if N is a matrix with size(N) = size(tmap) each element of N specifies
the number of sampling
;         operations applied to the correspondign element of tmap
; q     = quantization step (same units of tmap)
; sigma = white noise sigma (same units of tmap)
; tmin  = minimum value for the quantized scale (same units of tmap)
; tmax  = maximum value for the quantized scale (same units of tmap)
; nbits = number of bits for the quantization
;
; M. Maris - 0.0 - 21 Nov 2001
;

;
; change this offset if you change the quantization mode
;
  qoffset = 1./2.

;
; maps initialization
;
  qmap = tmap
  rqmap = tmap

  if (n_elements(n) eq 0) then
     print,'Error: n shall contain 1 element or as many elements as tmap'
     return
```

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```
   endif

   if (n_elements(n) ne n_elements(tmap)) then
      print,'Error: n shall contain 1 element or as many elements as tmap'
      return
   endif


;
; quantized, averaged map
;
   if (n_elements(n) eq 1) then
   for r=1,n_elements(tmap) do
      if (n_elements(n) eq 1) then
         wn = random(n,0,sigma)
      endif else
         wn = random(n(r),0,sigma)
      endelse
      x = (tmap(r) - tmin + wn)
      x(where(x lt 0)) = 0
      x(where(x gt (tmax-tmin))) = tmax-tmin
      qx = floor(x/q)
      qmap(r) = float(sum(qx))/float(n)
   endfor

;
; reconstructed, quantized, averaged map
;

   rqmap = (qmap + qoffset) * q + tmin

end
```

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APPENDIX B   DRIVE_QPATCH

This section contains the listing of `drive_qpatch.pro`, which may be considered an example of use for `qpatch.pro`.

```
;
; drive_qpatch.pro 0.0 – 2001 Nov 11 – M. Maris
;
; an example of use of qpatch
;

;
; gets the various components
;

readfits,'component1.fits',c1,h
readfits,'component2.fits',c2,h

;
; combines them to obtain tmap
;

tmap = c1+c2

;
; quantized maps for 30 and 60 repetitions
;
; sigma = 1 mK
; q     = 0.5 mK
; tmin  =  q*2^15
; tmin  = -q*2^15

qmap,rqmap30,qmap30,tmap,n=30,q=0.5,sigma=1.,tmin=-0.5*2^16,tmax=0.5*2^15
qmap,rqmap60,qmap60,tmap,n=60,q=0.5,sigma=1.,tmin=-0.5*2^16,tmax=0.5*2^15

;
; writes the result
;

writefits,'rqmap30.fits',rqmap60,h
writefits,'rqmap60.fits',rqmap60,h
```

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