esrin

Via Galileo Galilei
Casella Postale 64
00044 Frascati
Italy
T +39 06 9418 01
F +39 06 9418 0280
www.esa.int

DOCUMENT

Guidelines for reverting Waveform Power to Sigma Nought for CryoSat-2 in SAR mode

Prepared by	**Salvatore Dinardo**
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Values in AGC calibration table have been updated	23/06/2016	21	Annex A
PTR Power drift for SAR RX1 has been updated	23/06/2016	23	Annex B
Annex C on FFT implementation has been added	23/06/2016	24	Annex C

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REFERENCES & APPLICABLE DOCUMENTS

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[AD1]: Level 1b Products Formats Specifications, CS-RS-ACS-5106, Issue 6.4, (available at https://earth.esa.int/documents/10174/125273/CryoSat_L1_Products_Format_Specification)

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ACRONYMS & GLOSSARY

Along-Track Direction: direction parallel to the flight direction
Across-Track Direction: direction perpendicular to the flight direction
AGC: Automatic Gain Control
ADC: Analog to Digital Converter
Burst: A series of transmitted radar pulses in sequence
CoM: Center of Mass
FBR: Full Bit Rate: Un-calibrated Complex (I and Q) Individual Echoes posted at full PRF rate and deramped in time domain
DFT: Dicrete Fourier Transform
FFT: Fast Fourier Transform
FFTW: Fastest Fourier Transform in the West
IPF: Instrument Processing Facility
L1a: Level 1a
L1b: Level 1b
LPF: Low Pass Filter
LRM: Low Rate Mode (aka PulseWidth-Limited Altimetry)
PDGS: Payload Ground Segment
PRF: Pulse Repetition Frequency
PTR: Point Target Response
P_u: Waveform Power Value in output of the re-tracking stage
RF: Radio-Frequency
Rx: Receiving Chain
RDSAR: Reduced SAR
SAR: Synthetic Aperture Radar
Tx: Transmitting Chain

1 INTRODUCTION

The scope of this Technical Note is to feature know-how and recipes in order to extract the sigma nought information from CryoSat-2 data products in SAR mode.
The input data product for the present Technical Note is assumed to be either the CryoSat-2 PDGS SAR FBR Data Products **[AD1]** either the CryoSat-2 PDGS SAR L1b Data Products **[AD1]**.
The document is structured in four main headings:

- Calibration in power for SAR FBR individual echoes
- Calibration in power for SAR L1b waveforms
- Pu Extraction from Calibrated for SAR L1b waveforms
- Sigma Nought Retrieval from Waveform for SAR L1b waveforms

The user should follow different steps depending on
- the CryoSat-2 SAR product : FBR or L1B;
- the CryoSat-2 SAR product Baseline: BaselineB or BaselineC (see **[RD9]** for more details on the CryoSat-2 BaselineC L1b products).

In particular, the following steps shall be applied by the users:
- the users starting its own processing from CryoSat-2 SAR FBR shall follow in row the section 2 (according to section 2.2 in case of BaselineB FBR products or according to section 2.3 in case of BaselineC FBR products), section 4 and finally section 5;
- the users starting from BaselineB PDGS Cryosat-2 SAR L1B data products shall go through section 3.1, section 4 and then section 5.
- the users starting from BaselineC PDGS Cryosat-2 SAR L1B data products shall go through section 0, section 4 and then section 5.

It is worth underlining here that section 2 is only applicable for users who subsequently intend to generate their own SAR L1b but is not applicable for users who intend to generate the Pseudo LRM (RDSAR) L1b. A separate Technical Note will be released to address the issue of the LRM and Pseudo-LRM sigma-nought extraction.
This note intends to be complementary to **[RD3]** wherein the Delay-Doppler Processing is outlined.
The Technical Note, in this first initial issue, is dedicated exclusively to CryoSat-2 Radar Altimeter (SIRAL). Subsequently, in the next releases, the document will be augmented with more specific information relative to the Sentinel-3 Radar Altimeter (SRAL) gain calibration process.

2 FBR INDIVIDUAL ECHOES CALIBRATION IN POWER

This section lists the steps to undertake to calibrate in power the SAR FBR individual echoes waveforms. After waveform calibration, in order to generate calibrated and multi-looked SAR L1b waveforms, user subsequently should carry out a standard Delay-Doppler processing (as for instance outlined in **[RD3]**).
In the Delay-Doppler algorithm that we consider to be executed after the FBR waveform power calibration, we assume in this section that will not be any Hamming Window weighting application on burst echoes.
If, instead, user prefers to apply the Hamming Window Weighting (as done in CryoSat-2 PDGS), user needs to remind to compensate in power the application of the Hamming window weighting (as described in this Technical Note at section 3.1.1).
In addition, user needs to bear in mind that, in order to not alter the received power level, during the Receiver Transfer Function Mask Calibration (aka CAL2) **[RD3]**, the applied LPF Mask must be always normalized. For a thorough description of the calibration corrections to be applied by users to FBR data, please refer to **[RD10]**.
Finally, we assume in this section that the FFT implementation utilized by user is in line with the definition given in Annex C.
The nomenclature in the following formulations stands for Receiving Chain 1 (Rx1); but analogous formalism stands for Rx2.

2.1 Power Gain: Static Part

Evaluation of the Static Part for the Power Gain:

$$\begin{cases} \text{Gain\_ADC} = 10 \cdot \log 10(\text{ADC\_MULT}^2) \\ \text{Gain\_Proc\_Range} = 10 \cdot \log 10(\text{N}_s^2) \\ \text{Gain\_Proc\_Doppler} = 10 \cdot \log 10(\text{N}_b^2) \end{cases} \quad (1)$$

$$\text{Gain\_Digital} = \text{GAIN\_ADC} + \text{GAIN\_Proc\_Range} + \text{GAIN\_Proc\_Doppler}$$

$$\text{Gain\_Static\_Rx1} = \text{Gain\_RF\_Rx1} + \text{Gain\_Digital} \quad (2)$$

where:

ITEM	DESCRIPTION	SOURCE/VALUE
GAIN_RF_Rx1	RF Power Gain for Rx1 Chain	Field 22 in SAR FBR format structure (and expressed in dB)
ADC_MULT	ADC Multiplier Factor	to be extracted from IPF database, default value 1000
Ns	Number of SAR FBR Echo Samples	to be extracted from IPF database, default value 128
N_b	Number of Pulses in a Burst	to be extracted from IPF database, default value 64

GAIN_Proc_Range and GAIN_Proc_Doppler are the gains by which the waveform power is amplified thanks to the Delay-Doppler processing that raw waveform undergoes along the L1b stages[1].
After an operation of pulse compression (in range or Doppler domain), the signal in frequency needs to be scaled by N*N where N is the number of signal's samples:
1. A first scale by N is necessary since, after pulse compression, the signal’s power is amplified by N (**[RD8]**) as a gain due to the coherent processing.
2. A second scale by N needs to be taken into account assuming that the FFT transform used by the user is not a unitary transformation. For more details please refer to Annex C.

2.2 Power Gain: Dynamic Part for Baseline B FBR products

Corrections for the Dynamic Part of the Power Gain:

1. Automatic Gain Control Setting Correction

$$AGC = (AGC\_Stage1 + AGC\_Stage2) \quad (3)$$

with:

ITEM	DESCRIPTION	SOURCE/VALUE
AGC_Stage1	Uncorrected AGC Setting Value for Rx Chain Stage 1	Field 20 in SAR FBR format structure (and expressed in dB)
AGC_Stage1	Uncorrected AGC Setting Value for Rx Chain Stage 2	Field 21 in SAR FBR format structure (and expressed in dB)

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2. Correction for the instrument Gain

This correction is the sum of the delta AGC command (Delta AGC_RX1) and the PTR power drift (PTR Power_Drift_RX1).

In Baseline B, because of a bug in the IPF, the user is advised to compute on its own as sum of:

$$\text{Ins\_Gain\_Rx1} = \text{Delta\_AGC\_Rx1} + \text{PTR\_Power\_Drift\_Rx1} \quad (4)$$

where:

$$\text{PTR\_Power\_Drift\_Rx1} = \frac{\text{PTR\_Power\_Drift\_Month\_Slope\_Rx1}}{30 \cdot 24 \cdot 60 \cdot 60} \cdot \text{Time\_Counter} \quad (5)$$

with:

ITEM	DESCRIPTION	SOURCE/VALUE
PTR_Power_Drift_Month_Slope_Rx1	Slope by month of PTR Power Drift (see Annex B)	estimated to be -0.016 dB/month
Time_Counter	Number of seconds elapsed from 11 November 2010 (beginning of operational phase) to the sensing time	

and where:

$$\text{Delta\_AGC\_Rx1} = \text{AGC\_Table\_Rx1}\left(\text{AGC\_Stage1} + \text{AGC\_Stage2} \right) \quad (6)$$

with:

ITEM	DESCRIPTION	SOURCE/VALUE
AGC_Table_Rx1	AGC Calibration Table applicable for Rx1 chain	Extracted from IPF database
AGC_Stage1	Uncorrected AGC Setting Value for Stage 1	Field 20 in FBR format structure (and expressed in dB)
AGC_Stage2	Uncorrected AGC Setting Value for Stage 2	Field 21 in FBR format structure (and expressed in dB)

Evaluation of the Dynamic Part for the Power Gain:

$$Gain\_Dynamic\_Rx1 = AGC + Ins\_Gain\_Rx1 \qquad (7)$$

2.3 Power Gain: Dynamic Part for Baseline C FBR products

Corrections for the Dynamic Part of the Power Gain:

1. Automatic Gain Control Setting Correction

$$\text{AGC} = (\text{AGC\_Stage1} + \text{AGC\_Stage2}) \qquad (8)$$

with:

ITEM	DESCRIPTION	SOURCE/VALUE
AGC_Stage1	Uncorrected AGC Setting Value for Rx Chain Stage 1	Field 20 in SAR FBR format structure (and expressed in dB)
AGC_Stage1	Uncorrected AGC Setting Value for Rx Chain Stage 2	Field 21 in SAR FBR format structure (and expressed in dB)

2. Correction for the instrument Gain

   This correction is the sum of the delta AGC command (Delta AGC_RX1) and the PTR power drift (PTR Power_Drift_RX1).

   In Baseline C, this correction is reported in the FBR field 28 (reader minds to express it in db), that is:

$$\text{Ins\_Gain\_Rx1} = \text{Field 28 in SAR L1b format structure (in db)} \qquad (9)$$

Evaluation of the Dynamic Part for the Power Gain:

$$Gain\_Dynamic\_Rx1 = AGC + Ins\_Gain\_Rx1 \qquad (10)$$

2.4 Total Power Gain

Evaluation of the Total Power Gain:

$$\mathrm{Gain\_Rx1} = \mathrm{Gain\_Dynamic\_Rx1} + \mathrm{Gain\_Static\_Rx1} \tag{11}$$

Conversion from decibel scale to linear scale and Gain application in amplitude to FBR Amplitude Echoes:

$$\mathrm{FBR\_Burst\_Echo\_Rx1} = \mathrm{FBR\_Burst\_Echo\_Rx1} \cdot \sqrt{10^{-\left(\frac{\mathrm{Gain\_Rx1}}{10}\right)}} \tag{12}$$

where:

ITEM	DESCRIPTION	SOURCE/VALUE
FBR_Burst_Echo_Rx1	Individual Echoes (Amplitude) from SAR FBR Burst (Rx1 Chain)	Field 51 in SAR FBR format structure

3 SAR L1B WAVEFORM CALIBRATION IN POWER

3.1 SAR L1B waveforms from Baseline B L1B products

This section lists the steps to undertake to convert in watt units the SAR L1b waveforms as stored in CryoSat-2 PDGS SAR L1b data products, as defined in **[AD2]**.
The listed instructions stand for the CryoSat-2 L1b SAR data products in the **Baseline-B** generation.
Working with the CryoSat-2 PDGS SAR L1b Waveforms, user needs to bear in mind that in the CryoSat-2 IPF1 PDGS, the adopted FFT implementation is the FFTW which is not an unitary DFT; in order to get the DFT finally unitary in the CryoSat-2 IPF1 PDGS, the output of DFT (as defined in Annex C) is further divided by the normalization constant $\sqrt{N_{FFT}}$, where N_{FFT} is the number of samples on which the DFT is executed.

3.1.1 Static Corrections

Static Corrections to be applied to the Baseline B PDGS SAR L1b Power Waveforms

- Compensation for Zero-Padding Scale Factor

In CryoSat-2 PDSG Baseline B, the range FFT is executed by default on 256 samples, instead than 128 (zero-padding operation with oversampling factor of 2 **[RD1])** and hence the range FFT (since in CryoSat-2 L1b PDGS, the unitary DFT definition is used) is divided by sqrt(256) factor. This introduces a fictitious attenuation by a factor 2 that needs to be compensated amplifying in dB the power level by:

$$\text{SCALE\_ZP} = 10 \cdot \log10(\text{os\_ZP}) \qquad (13)$$

where:

ITEM	DESCRIPTION	SOURCE/VALUE
os_ZP	Zero-Padding Oversampling Factor	default value 2 in Baseline B

- Compensation for Azimuth FFT Samples Number

In CryoSat-2 PDSG Baseline B, due to the azimuth unitary DFT, the power level is scaled only by a N_b factor but a further scale by N_b is still missing; hence, we need to attenuate in dB further the power level by:

$$\mathrm{SCALE\_Az\_F\,FT} = 10 \cdot \log 10(N_b) \qquad (14)$$

where:

ITEM	DESCRIPTION	SOURCE/VALUE
N_b	Number of Pulses in a Burst	to be extracted from IPF database, default value 64

- Compensation for Hamming Weighting Application

In the CryoSat-2 PDSG Baseline B, an Hamming weighting window of length N_b is applied in azimuth direction to all samples of all individual echoes of every burst at the very beginning of the beam-forming stage **[RD1]**.
The side-effect of Hamming weighting application is to alter the burst individual echoes power level. This power alteration is not compensated in Baseline-B and users need to compensate by themselves. A way to estimate roughly the amount of scaling to apply in dB is the following:

$$\mathrm{SCALE\_HAM} = 10 \cdot \log 10\left[\left(\frac{1}{N_b}\left(\sum_i \mathrm{HAM\_Func}_i\right)\right)^2\right] \qquad (15)$$

where:

$$\begin{cases} \mathrm{HAM\_Func}_i = c1 + c2 \cdot \left[\cos\left(\frac{\pi \cdot x_i}{N_b - 1} - \frac{\pi}{2}\right)\right]^2 \\ x_i = 0,..,N_b - 1 \end{cases} \qquad (16)$$

ITEM	DESCRIPTION	SOURCE/VALUE
N_b	Number of Pulses in a Burst	to be extracted from IPF database, default value 64
c1	First Hamming constant	default value 0.08 in Baseline B
c2	Second Hamming constant	default value 0.92 in Baseline B

3.1.2 Dynamic Corrections

Dynamic Corrections to be applied to the PDGS SAR L1b Power Waveforms

- PTR Power Drift Correction

In Baseline B, the PTR power drift correction is not applied and users need to apply it by themselves:

$$\mathrm{PTR\_Power\_Drift\_Rx1} = \frac{\mathrm{PTR\_Power\_Drift\_Month\_Slope\_Rx1}}{30 \cdot 24 \cdot 60 \cdot 60} \cdot \mathrm{Time\_Counter} \quad \textbf{(17)}$$

where:

ITEM	DESCRIPTION	SOURCE/VALUE
PTR_Power_Drift_Month_Slope_Rx1	Slope by month of PTR Power Drift (see Annex B)	estimated to be -0.016 dB/month
Time_Counter	Number of seconds elapsed from 11 November 2010 (beginning of operational phase) to the sensing time	

3.1.3 Conversion of PDGS SAR L1b Waveforms from Counts to Calibrated Watts (Baseline B)

The conversion from the scaled version of the power waveform (counts) to the un-scaled and calibrated power waveform (watts) is performed according to the following formula:

$$\mathrm{SAR\_Power\_Echo\_Rx1} = \left[\left(10^{-9} \cdot \mathrm{A} \cdot 2^{\mathrm{B}}\right) \cdot \mathrm{SAR\_Power\_Echo\_Rx1} \right] \cdot \\ \cdot 10^{-\left(\frac{\mathrm{PTR\_Power\_Drift\_Rx1}}{10}\right)} \cdot 10^{-\left(\frac{\mathrm{SCALE\_HAM}}{10}\right)} \cdot 10^{\left(\frac{\mathrm{SCALE\_ZP}}{10}\right)} \cdot 10^{-\left(\frac{\mathrm{SCALE\_Az\_FFT}}{10}\right)} \tag{18}$$

where:

ITEM	DESCRIPTION	SOURCE/VALUE
SAR_Powe_Echo_Rx1	L1b SAR Multilooked Power Echo (Rx1 Chain)	Field 76 in SAR L1b format structure in [AD2]
A	Echo Scale Factor	Field 77 in SAR L1b format structure in [AD2]
B	Echo Scale Power	Field 78 in SAR L1b format structure in [AD2]

3.2 SAR L1B waveforms from Baseline C L1B products

This section lists the steps to undertake to convert in watt units the SAR L1b waveforms as stored in CryoSat-2 PDGS SAR L1b data products, as defined in **[AD1]**.
The listed instructions stand for the CryoSat-2 L1b SAR data products in the **Baseline C** generation.
Working with the CryoSat-2 PDGS SAR L1b Waveforms, user needs to bear in mind that in the CryoSat-2 IPF1 PDGS, the adopted FFT implementation is the FFTW which is not an unitary DFT; in order to get the DFT finally unitary in the CryoSat-2 IPF1 PDGS, the output of DFT (as defined in Annex C) is further divided by the normalization constant $\sqrt{N_{FFT}}$, where N_{FFT} is the number of samples on which the DFT is executed.
Furthermore, working with the CryoSat-2 PDGS SAR L1b Waveforms in BaselineC, we have to bear in mind that the following corrections are already applied on the L1b waveforms **[RD9]** (and hence they don't need to be re-applied):

- Compensation for Zero-Padding Scale Factor
- Compensation for Azimuth FFT Samples Number
- PTR Power Drift Correction
- Compensation for Hamming Weighting Application

3.2.1 Conversion of PDGS SAR L1b Waveforms from Counts to Calibrated Watts (Baseline C)

The conversion from the scaled version of the power waveform (counts) to the un-scaled and calibrated power waveform (watts) is performed according the following formula:

$$SAR\_Power\_Echo\_Rx1 = \left[(10^{-9} \cdot A \cdot 2^{B}) \cdot SAR\_Power\_Echo\_Rx1\right] \cdot \qquad (19)$$

where:

ITEM	DESCRIPTION	SOURCE/VALUE
SAR_Powe_Echo_Rx1	L1b SAR Multilooked Power Echo (Rx1 Chain)	Field 81 in SAR L1b format structure in [AD1]
A	Echo Scale Factor	Field 82 in SAR L1b format structure in [AD1]
B	Echo Scale Power	Field 83 in SAR L1b format structure in [AD1]

4 P_U EXTRACTION FROM CALIBRATED POWER WAVEFORM

$\mathbf{P_u}$ is herein defined as the waveform power value in output of the re-tracking stage.
$\mathbf{P_u}$ is meant to be a measurement of the received signal power at antenna's flange.
From **Calibrated** and **Multilooked** L1b SAR Power Waveforms, the quantity Pu is extracted according to methodologies outlined in **[RD4]**.
In the CryoSat-2 L1b PDGS (**Baseline B & C**), the multi-looked SAR Power Waveform is scaled by the total number of accumulated looks and, along the Delay-Doppler stack, is not applied by default any antenna pattern weighting compensation or stack weighting.
Further, since Baseline C, the looks are accumulated within a specific span of look angles. This span of look angles is specified by the look angle of the first (Beam Parameter ID 10 from Field 86 in SAR L1b format structure according to **[AD1]**) and last (Beam Parameter ID 11 from Field 86 in SAR L1b format structure according to **[AD1]**) contributing beam in the stack.
Hence, for a consistent Pu extraction from CryoSat-2 L1b SAR Power Waveforms, the SAR Return Power Model (utilized at L2 in the re-tracking scheme) should replicate as much as possible the same multi-look algorithmic scheme as used in the PDGS L1b multi-looking stage; hence:

- the multi-looked echo **model** should be generated accumulating the same number of looks as used to generated the L1b SAR Power Waveforms. In case of BaselineB L1B products, this number is reported in Field 79 in SAR L1b format structure, according to **[AD2]**. In case of BaselineC L1B products, this number is reported in Field 84 in SAR L1b format structure, according to **[AD1]**;
- the multi-looked echo **model** should be scaled by this number of accumulated looks;
- the multilooking should run from the first look angle to the last look angle, annotated in BaselineC only in Beam Parameter ID 10 and Beam Parameter ID 11, respectively, from Field 86 in SAR L1b format structure according to **[AD1]**;
- the antenna pattern parameters should be set according to **[RD10]**;
- the antenna pattern weighting compensation should not be applied along the modelled Delay-Doppler stack.

In output of the re-tracking scheme, Pu needs to be expressed in watts and be de-noised (i.e. the thermal noise contribution should not be included in Pu).

5 SIGMA NOUGHT RETRIEVAL FROM P_U

The sigma nought (dB) is derived from Pu (watts) inverting the SAR Radar Link Equation[2]. The link is between the reflection surface and the antenna's flange[3]. Hence, the SAR Radar Link Equation is given by:

$$\sigma_0 = 10 \cdot \log 10\left(\frac{P_u}{Tx\_Pwr}\right) + 10 \cdot \log 10(K) + bias\_sigma\_0 \tag{20}$$

where:

$$K = \frac{(4\pi)^3 \cdot R^4 \cdot L_{atm} \cdot L_{RX}}{\lambda_0^2 \cdot G_0^2 \cdot A_{SAR}} \tag{21}$$

where A_{SAR} is the resolution ground-cell in SAR-mode:

$$A_{SAR} = (2 \cdot L_y) \cdot (wf \cdot L_X) \tag{22}$$

with:

$$\begin{cases} L_y = \sqrt{\dfrac{c_0 \cdot R \cdot PTR\_width}{\alpha_{Earth}}} \\ L_x = \dfrac{\lambda_0 \cdot R}{2 \cdot V_s \cdot \tau_B} \end{cases} \tag{23}$$

and

$$\alpha_{Earth} = 1 + \frac{R}{R_\oplus} \tag{24}$$

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[2] The processing gains in range and Doppler are already applied at L1b stage (section2), hence they don't need to be included in the above radar equation.

[3] Apart for the residual RF losses that are here included in the radar link equation because they have not been compensated in section 2.

ITEM	DESCRIPTION	SOURCE/VALUE
R	Range from Satellite CoM to surface reflection point	output of the re-tracker scheme and expressed in meter
Tx_Pwr	Transmitted Peak Power[4]	Field 24 in SAR FBR format structure (and expressed in watts)
L_{atm}	Two Ways Atmosphere Losses	to be modelled and expressed dimensionless in linear scale
L_{RX}	Receiving Chain (RX) Waveguide Losses	to be characterized and expressed dimensionless in linear scale
λ_0	Radar Wavelength	to be extracted from IPF database, and expressed in meter, default value 0.022084 m
c_0	Speed light in vacuum	299792458 m/sec
wf	footprint widening factor[5]	1 in case of no weighting window application and $1.486 \cdot rv$ in case of Hamming window application on burst data[6]
$R_{\oplus}$	Mean Earth Radius	6371000 m
G_0	Antenna Gain at Boresight	10^(4.28): from [RD10] and expressed in linear scale.
PTR_width	3dB Range Point Target Response Temporal Width	to be extracted from IPF database, and expressed in sec, default value 2.819e-09 sec
V_s	Satellite Along Track Velocity	From Field 11 in SAR FBR format structure and expressed in m/sec
τ_B	Burst Length	to be extracted from IPF database, and expressed in sec, default value 0.00352 sec
bias_sigma_0	CryoSat-2 System Bias for sigma nought (dB)	to be defined

[4] This term takes in account also the transmitting chain waveguide losses.
[5] This widening factor is due to the enlargement of the along-track ground resolution as consequence of weighting window application.
[6] **rv** is a residual factor estimated empirically. This estimation may be carried out measuring the power level difference obtained once not activating the Hamming window weighting and once activating it for passes over open sea.

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- Michele Scagliola
- Bruno Lucas
- Jerome Benveniste

7 ANNEX A

AGC Calibration Table applicable for Rx1 chain

AGC Setting VALUE	AGC SETTING DELTA
62	-0,53
61	-0,38
60	-0,40
59	-0,35
58	-0,27
57	-0,26
56	-0,40
55	-0,32
54	-0,24
53	-0,23
52	-0,15
51	-0,26
50	-0,34
49	-0,33
48	-0,24
47	-0,39
46	-0,30
45	-0,30
44	-0,21
43	0,03
42	0,11
41	0,12
40	-0,02
39	0,07
38	0,15
37	0,16
36	0,24
35	0,13
34	-0,04
33	0,03
32	-0,11
31	-0,02
30	0,06
29	0,07
28	0,15
27	0,04
26	0,13
25	0,11
24	0,21
23	-0,03
22	0,05
21	0,02
20	0,12

19	0,39
18	0,49
17	0,44
16	0,55
15	0,42
14	0,52
13	0,48
12	0,58
11	0,45
10	0,61
9	0,42
8	0,33
7	0,41
6	0,51
5	0,45
4	0,56
3	0,42
2	0,53
1	0,47
0	0,57

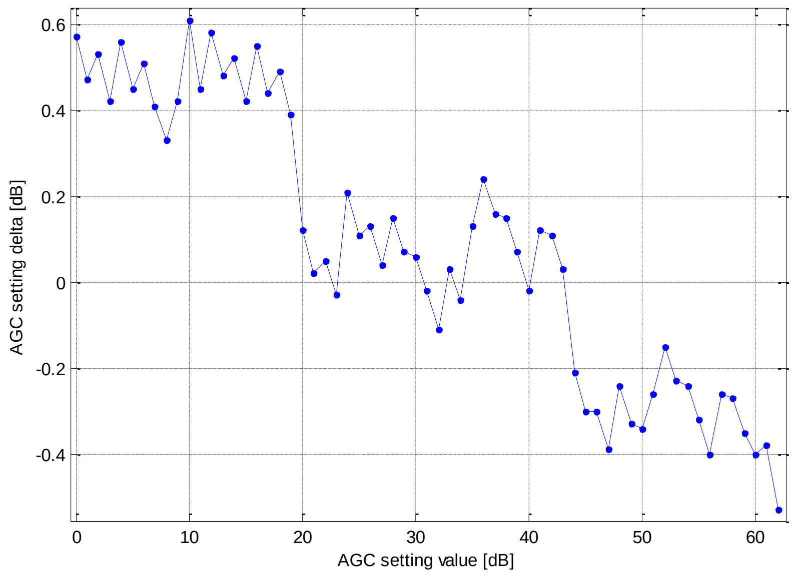
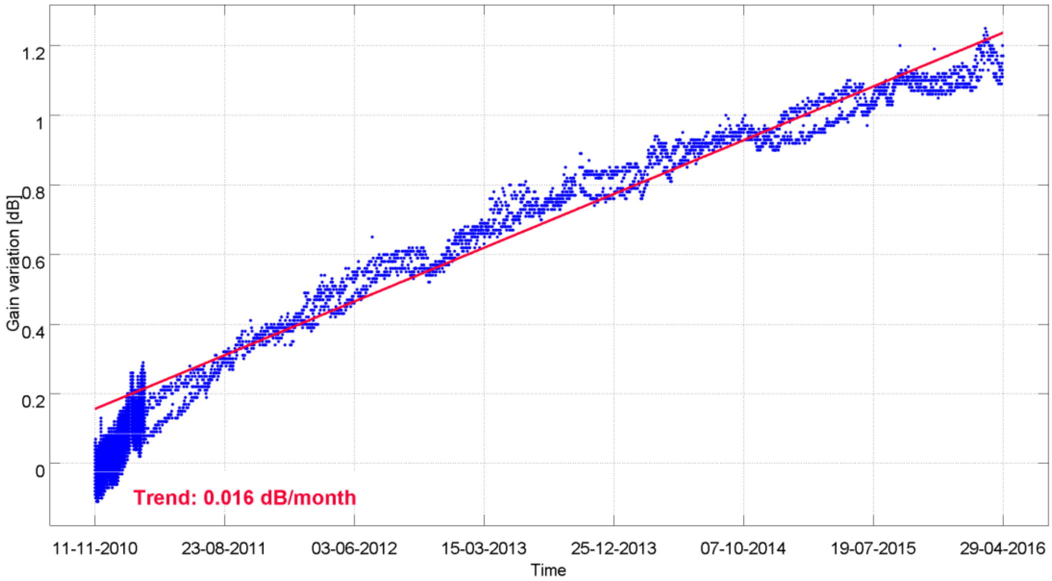


Figure 1: AGC Calibration Table applicable for Rx1 chain

8 ANNEX B

SAR RX1 PTR Power Drift

The following plot shows the PTR Power drift for SAR RX1, extracted from CAL1 corrections. CAL1 is performed over a zone over in-land Asia.
The starting date considered in this document is 11 November 2010, day of beginning of the operational phase using SIRAL-A.
The power drift can be characterized by a linear decay estimated to be around -0.016 dB/month, which is compensated by the CAL1 PTR power corrections depicted below.



9 ANNEX C

FFT implementation

Throughout this document, it has been assumed that a not unitary Fast Fourier Transform (FFT) implementation is used. A not unitary FFT implementation is defined according to the one in **[RD5]** and, for instance, implemented by the FFTW algorithm **[RD6]**.

Not unitary FFT is defined as in the following formula

$$X_k = \sum_{n=0}^{N-1} x_n \cdot \exp\left(-j2\pi k \frac{n}{N}\right), \qquad n = 0,\ldots,N-1 \tag{25}$$

and the corresponding Inverse Fast Fourier Transform (IFFT) is defined as in the following formula

$$x_n = \frac{1}{N} \sum_{k=0}^{N-1} X_k \cdot \exp\left(j2\pi n \frac{k}{N}\right), \qquad k = 0,\ldots,N-1 \tag{26}$$

where the factor 1/N in the IFFT definition is required to guarantee that $IFFT\left(FFT\left(x_n\right)\right) = x_n$.