JASON-1 ALTIMETER WAVEFORMS RETRACKING ALGORITHM

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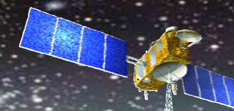
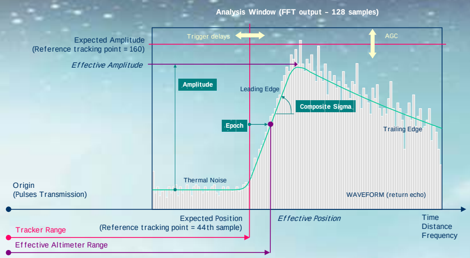


1) Why ?



Reasons why the effective parameters are different from the expected ones

For each waveform (i), the analysis window is set in distance and amplitude by the on-board Tracking function, from the Trigger delays and the Automatic Gain Control **quantized estimates** derived from the real-time analysis of **waveform i-2** (analysis performed during the building of waveform i-1).

Trigger delays are derived from the outputs of **a second order loop filter**, which estimates the distance and its first derivative in Ku-band (acceleration is ignored). AGCs are derived from the outputs of **first order loop filters**, which estimate the amplitude in Ku and in C bands.

The error signals on input of these loop filters are determined by balancing the return power in three fixed windows, accounting for a **simplified ocean echo model**.

Loop gains are **optimized for the Tracking function** (ability to follow rapid evolutions of distance and/or amplitude).

Aim of the retracking

To estimate the Epoch, the Amplitude and the Composite Sigma, in order to retrieve the **accurate** estimates of :

Altimeter Range	= Tracker Range + Epoch (0 without retracking)
Backscatter Coefficient	= «Radar equation» + AGC + Amplitude (about 160 without retracking)
Significant WaveHeight	= 2c.Sqrt (SigmaC**2-SigmaP**2), SigmaP = PTR width

Feature of the retracking

Full decorrelation of the 20-Hz estimates.

2) How ?

Hayne G.S. 1980
«Radar Altimeter Mean Return Waveforms from Near-Normal-Incidence Ocean Surface Scattering»
IEEE Trans. on antennas and propagation, Vol.AP-28, n°5

To make the measured waveforms coincide with a **return power model** (accounting in particular for mispointing and skewness, and assuming a gaussion Point Target Response), according to weighted Least Square Estimators derived from Maximum Likelihood Estimators.

MATHEMATICAL DESCRIPTION

Probability density of the noise affecting the individual echoes (V = 20-Hz waveform, $\overline{V}$ = model, i = sample, j = pulse - PRF) → $p(V_{ij}) = \frac{1}{\overline{V}_i}.\exp\left(-\frac{V_{ij}}{\overline{V}_i}\right)$

Likelihood function (assuming no correlation between samples) → $\Lambda = \prod_{i,j} p(V_{ij}) = \prod_{i,j} \frac{1}{\overline{V}_i}.\exp\left(-\frac{V_{ij}}{\overline{V}_i}\right)$

System to solve = Maximization of the Logarithm of the Likelihood function ({θk} = Epoch, SigmaC, Amplitude) → $\frac{\partial Ln(\Lambda)}{\partial \theta_k} = 0 \Leftrightarrow \sum_i \frac{\overline{V}_i - V_i}{\overline{V}_i^2}.\frac{\partial \overline{V}_i}{\partial \theta_k} = 0$

Equivalent to → $B.D = 0 \quad \left(B_{ki} = \frac{1}{\overline{V}_i}.\frac{\partial \overline{V}_i}{\partial \theta_k}, D_i = \frac{\overline{V}_i - V_i}{\overline{V}_i}\right)$

Iterative solution : development of the Cost function in Taylor series at the first order (n = iteration number, g = loop gain) → $\theta_{k\,n+1} = \theta_{k\,n} - g.(BB^T)^{-1}BD$

Weighting simplification to try not to put the most weight on the regions with the least information (Pu = Amplitude) → $B_{ki} = \frac{1}{P_u}.\frac{\partial \overline{V}_i}{\partial \theta_k}, D_i = \frac{\overline{V}_i - V_i}{P_u}$

MAIN STEPS OF THE PROCESSING

Loop (n=0 to max. allowed value)

- Initializations — Epoch, SigmaC and Amplitude set to default values
- Thermal noise estimation — Arithmetic averaging of samples of the first plateau
- Limitation of SigmaC(n)
- Computation of the echo model and partial derivatives (n) — Accounting for the platform or waveform-derived mispointing estimate
- Determination of matrixes B^T and D (n)
- Computation of the normalized MQE (n) — Mean Quadratic Error between the normalized waveform and the normalized echo model
- Resolution of system $B^T.X = D$ (n) — Computation of the error signal $X = (BB^T)^{-1}BD$ (without computing the inverse matrix)
- Update of the estimates (n+1) — Update of Epoch, SigmaC and Amplitude
- n < Min. allowed value ? — *Yes*
- Update of the echo model and of the normalized MQE (n+1)
- Conditions on MQE (n+1, n, n-1) OK ? — *No* — $1\text{-Threshold} < \frac{MQE(n)}{MQE(n+1)} < 1\text{+Threshold}$ and $1\text{-Threshold} < \frac{MQE(n-1)}{MQE(n+1)} < 1\text{+Threshold}$

3) Current Setting of the main Parameters

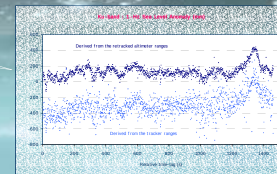
Skewness coefficient	0 (to be determined)
Origin of the mispointing estimation	Platform
Thermal noise window	14th to 18th sample
Epoch, SigmaC and amplitude window	14th to 116th sample
SigmaC minimum value (model and derivatives computation)	⇔ SWH = 0,25 m
SigmaC maximum value (model and derivatives computation)	⇔ SWH = 20 m
Minimum number of iterations	3
Maximum number of iterations	25
Epoch, SigmaC and amplitude loops gain	1
Threshold for the MQE ratio testing	5.10^{-4}

4) Behaviour, Examples

Ocean Measurements from April, 6th 2002
(02:37 - 03:02)

Ocean measurements from December, 14th 2001
(00:40 - 01:05)
Reference dataset for retracking validation

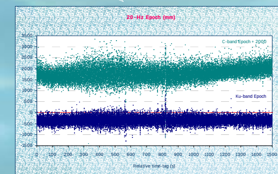
ALTIMETER RANGE



See Poster
"CMA – Altimeter Multimissions Center"

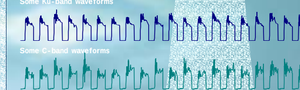
Retracking and Products Level

(I)GDR – Full precision On-Ground algorithm
OSDR – Simplified On-Board algorithm

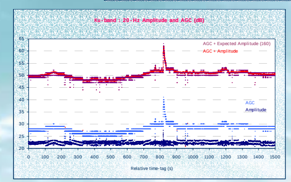


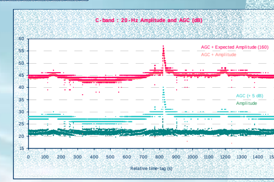
Some Ku-band waveforms

Some C-band waveforms

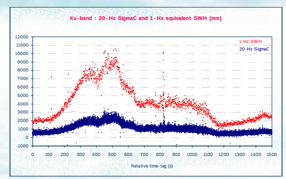


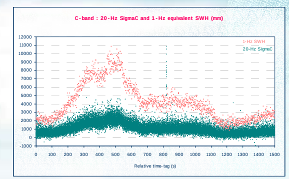
BACKSCATTER COEFFICIENT

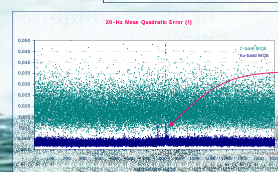


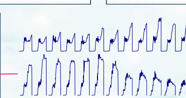


SIGNIFICANT WAVEHEIGHT

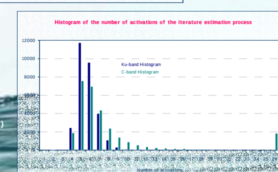


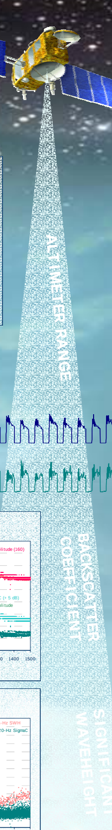






Non ocean-like waveforms (Ku-band for example)





Jason-1 Science Working Team Meeting

Biarritz, June 2002

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