

Theoretical Model of SAR Altimeter over Water Surfaces

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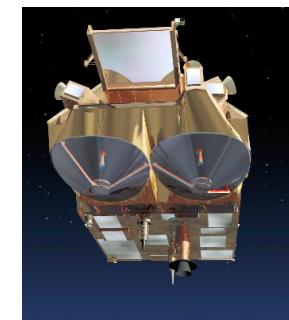
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- Introduction
- SAMOSA Overview
- Problem Formulation
- Theoretical Model for the Mean Return Echo Over Water surfaces
- Conclusions

- Brief overview of the objectives and methodology of the project **SAMOSA** (**esa** funded): **"Development of SAR Altimetry Studies and Applications over Ocean, Coastal zones and Inland waters"**
- Mainly concentrate on → the **development of a theoretical model for the mean return echo from a SAR altimeter observations over water surfaces**

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- The application of SAR techniques to classical radar altimetry offers a potential solution to significantly enhance Earth surface mapping
- CryoSat (2009) will be the first satellite to provide such data
- Data is of great interest to the Hydrosphere and Oceanographic communities since it would allow quantitative assessment of expected enhanced altimetric capabilities in coastal monitoring, ocean floor topography, gravity field and inland water monitoring.



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- SAMOSA kicked off in September 2007
- **FOCUS:** analyze the potentialities of advanced SAR Altimetry over water surfaces.

- **Team:**
 - Satellite Oceanographic Consultants (prime, SATOC, UK)
 - The Danish National Space Centre (NDSC, Denmark)
 - De Montfort University (DMU, UK)
 - The National Oceanography Centre (NOCS, UK)
 - Starlab Barcelona S.L (STARLAB, Spain)
- **External participation** of Dr. Raney (APL – Johns Hopkins University)

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CryoSat was designed for Cryosphere applications





Requirements for its application to **oceanographic observations**:

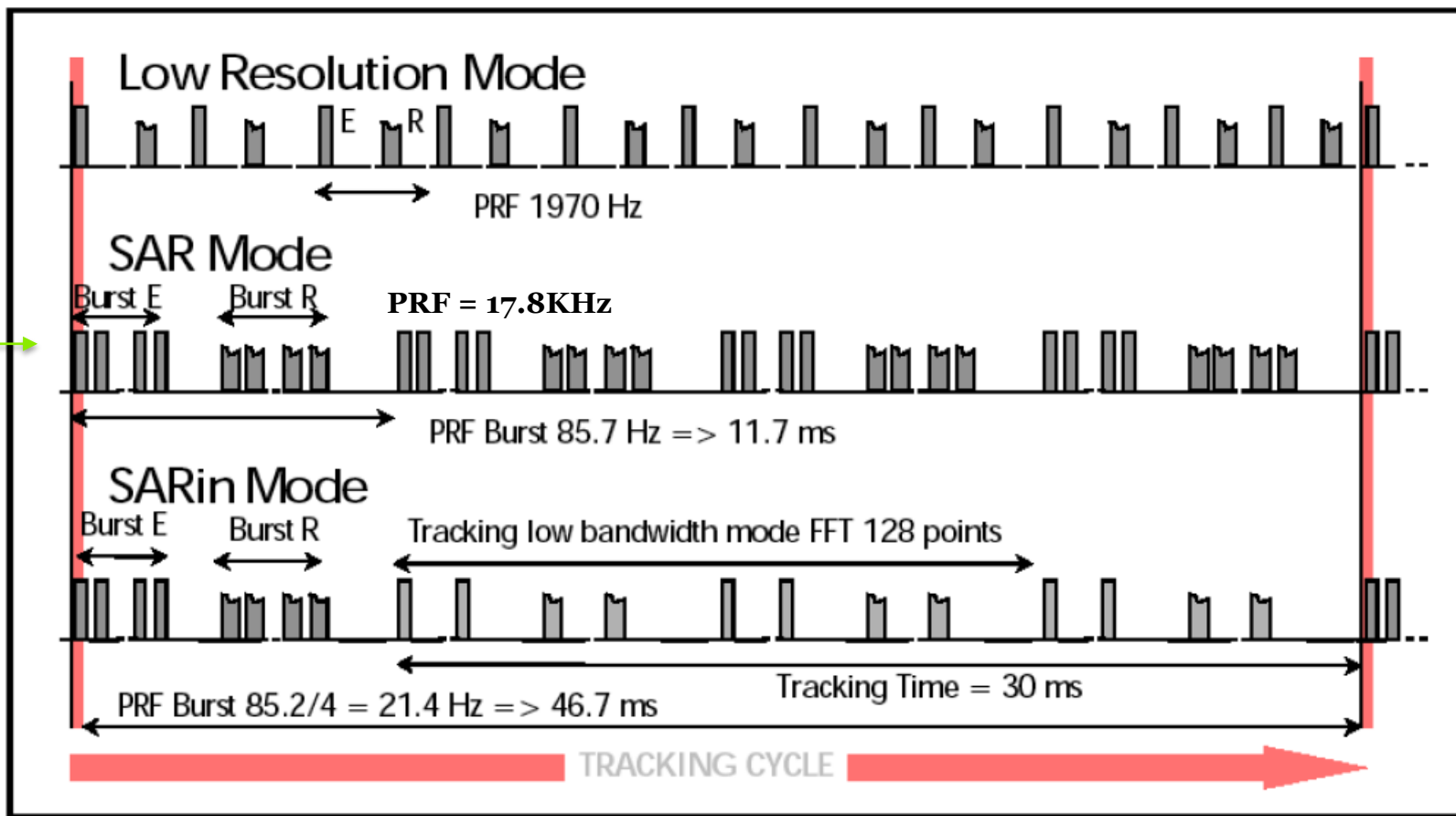


1. Retracker adapted to the specific nature of SAR altimeter echoes
2. Theoretical Model for the Mean Return Echo Over Water Surfaces in the same spirit set by conventional altimeters [Brown, 1977][Hayne, 1980]

- Introduction
- SAMOSA Overview
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- SAR Altimeter (aka Delay/Doppler altimeter) introduced by Dr. Keith Raney (1998)
 - Key innovation is the introduction of along track processing:
 - Increased Resolution
 - Multi-look processing
 - Technique requires echo delay compensation analogous to Range Cell Migration correction (conventional SAR)
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- Spatial resolution is increased in the along-track dimension.
 - Accumulation of more statistically independent looks for each scattering area
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- Better speckle reduction → finer precision of altimetric measurements.

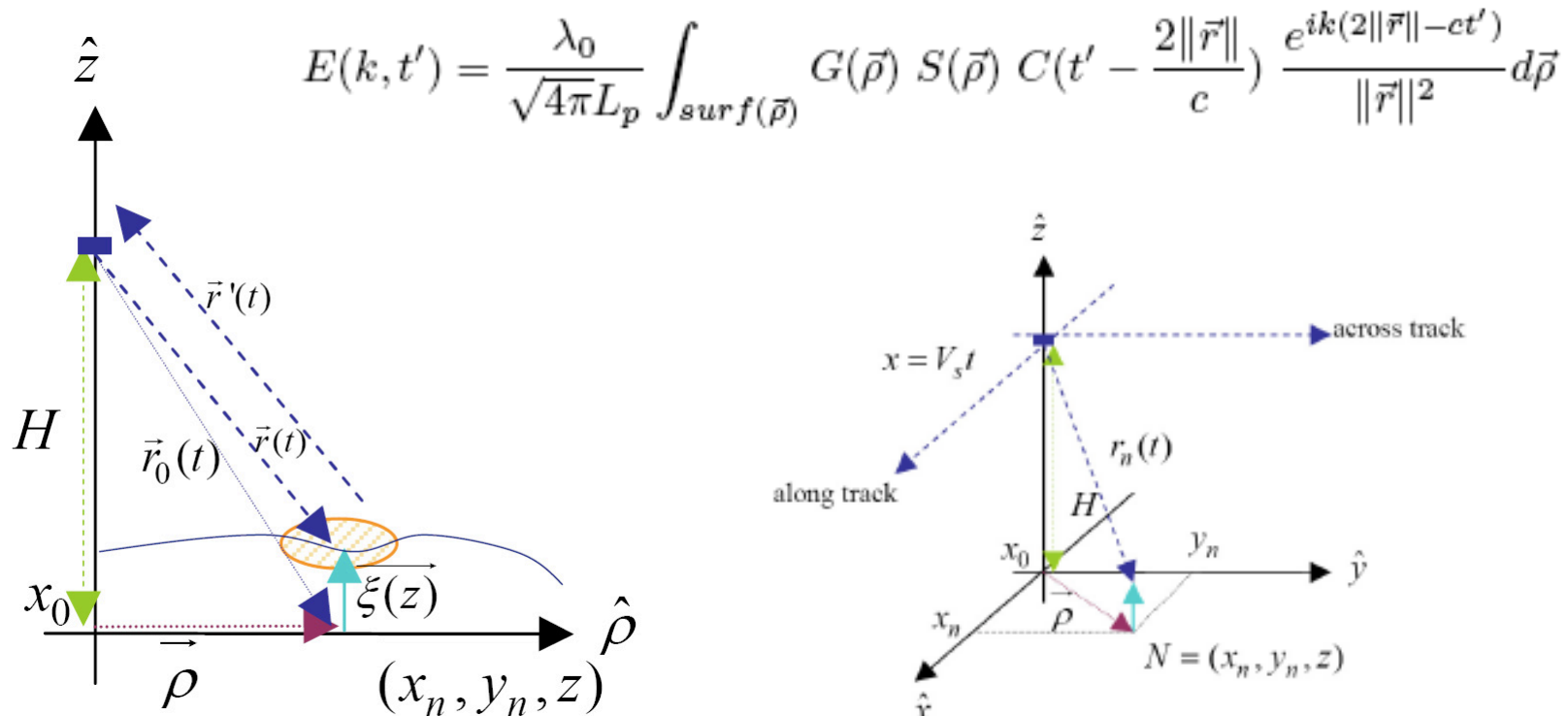
- Introduction
- SAMOSA Overview
- Problem Formulation
- **Theoretical Model for the Mean Return Echo Over Water Surfaces**
- Conclusions



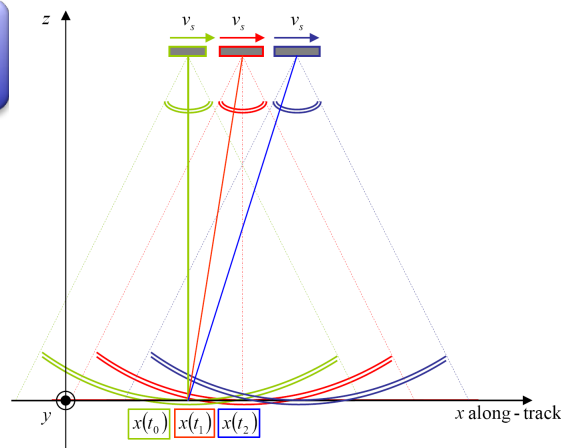
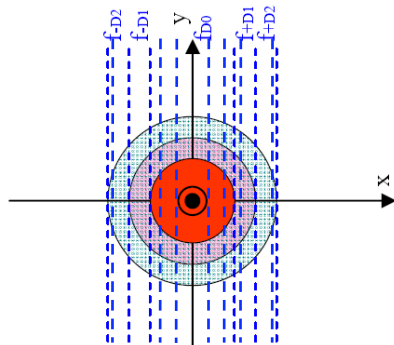
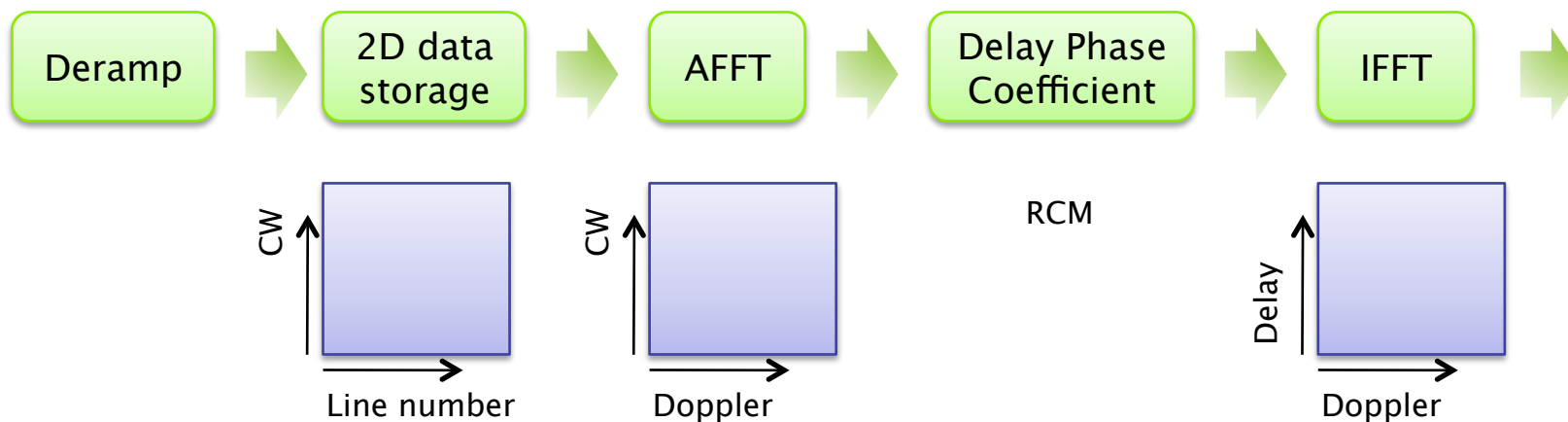
[Ref] Cyosat Mission and Data Description. Page 28th. ESA Doc No. CS-RP-ESA-SV-0059

- Introduction
- SAMOSA Overview
- Problem Formulation
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- Starting Point based on asymptotic expression of the field scattered by the ocean surface when illuminated by a quasi-monochromatic spherical wave in a frozen geometry (surface static during integration time within a burst)



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Considering static G, S during integration time

$$E_s(\tau, f_a; z) = \frac{\lambda_0}{\sqrt{4\pi L_p}} \int_{surf(\vec{\rho})} G(\vec{\rho}) S(\vec{\rho}) W(\tau, f_a; \vec{\rho}, z) \frac{e^{ik(2\|\vec{r}\|)}}{\|\vec{r}\|^2} d\vec{\rho}$$

$\|\cdot\|^2$



Accumulation

$$E[I_R]_z = E[E_s(\tau, f_a; z(\vec{\rho})) E_s^*(\tau, f_a; z(\vec{\rho}'))]_z$$

System point target response

$$S_R(\tau, f_a; \xi_\rho) = \|W(\tau, f_a; \xi_\rho)\|^2$$

Surface pdf of the specular points

$$E[I_R]_z = \frac{\lambda_0^2}{4\pi L_p^2 H^4} \int_{\xi_\rho} \|G(\xi_\rho)\|^2 \|S(\xi_\rho)\|^2 \sigma_0(\epsilon) S_R(\tau, f_a; \xi_\rho) * q_z(\tau) d\xi_\rho$$

- Introduction
- SAMOSA Overview
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- Conclusions

Flat Surface Impulse Response

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|| ||² → Accumulation $E[I_R]_z = P_{FS}(\tau; \xi_\rho, \epsilon) * S_R(\tau, f_a; \xi_\rho) * q_z(\tau)$

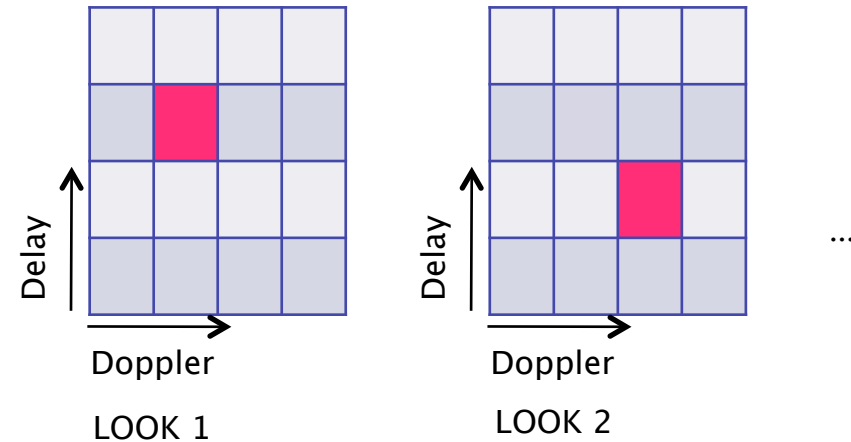
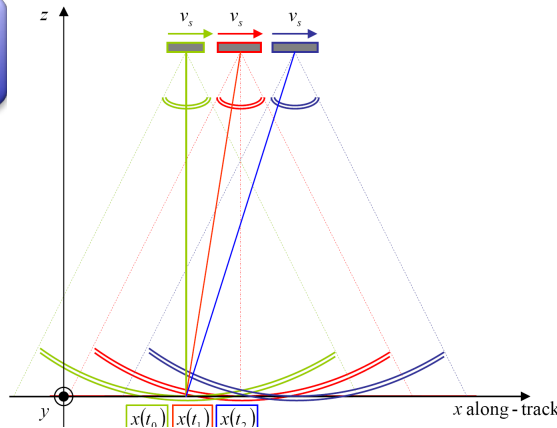
$$P_{FS}(\tau; \xi_\rho, \epsilon) = \frac{\lambda_0^2}{4\pi L_p^2 H^4} \int_{\xi_\rho} \|G(\xi_\rho)\|^2 \|S(\xi_\rho)\|^2 \sigma_0(\epsilon) \delta(\tau) d\xi_\rho$$

Assumptions done to arrive to this result:

.- $\Delta\rho \sim 0 \rightarrow$ Ocean Gaussian statistics

- Introduction
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Multi-Look

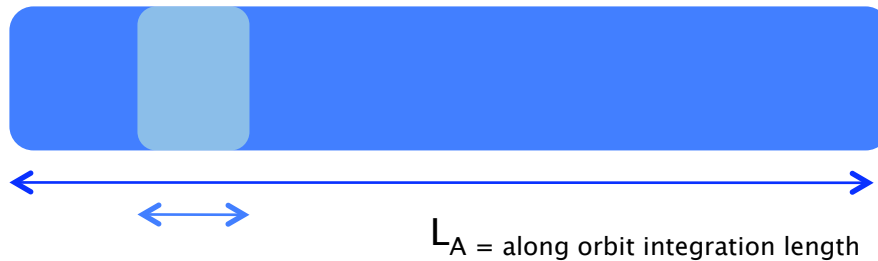


$$E[I_R]_z = \frac{\lambda_0^2}{4\pi L_p^2 H^4} \sum_{t_m} \int_{\zeta_\rho} \|G(\vec{\zeta}_\rho - \vec{V}_s t_m)\|^2 \|S(\vec{\zeta}_\rho - \vec{V}_s t_m)\|^2 \sigma_0(\epsilon - \epsilon') E[\|W(\tau_m, f_m; \vec{\zeta}_\rho - \vec{V}_s t_m)\|^2]_z d\zeta_\rho$$

If antenna gain, surface scattering amplitude, RCS and the system point target response remained the same we would be able to have the same mean intensity previous to multi-look multiplied by a factor M, which refers to the number of looks

$$E[I_R]_z = P_{FS}(\tau; \xi_\rho, \epsilon) * S_R(\tau, f_a; \xi_\rho) * q_z(\tau) \text{ M}$$

- Introduction
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$$M = \frac{T_i}{T} = \frac{L_A}{\delta_a}$$



$$M = \beta \sqrt{\frac{2H\alpha}{\lambda}}$$

If Brown (Brown, G.S., 1977) Flat surface impulse response solution is used, the mean intensity will have a H^{-3} dependence. With the M multiplying factor we achieve after multi-look a total mean intensity dependent on $H^{-5/2}$, which resembles the solution provided in (Raney, R.K, 1998)

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- The SAR Altimeter waveform before multi-look satisfies Hayne's model with a different System point target Response
- The System point target response of the SAR altimeter results in finer resolution
- Multi-look essentially suppresses further speckle noise
- Multi-look averaging results in an equivalent mean intensity received dependent on $H^{-5/2}$

Thanks For Your Attention!

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