CryoSat footprints

Aresys Technical Note

ESA Document REF	XCRY-GSEG-EOPG-TN-13-0013
Aresys Internal REF	SAR-CRY2-TEN-6331
Issue	1.1
Date	18 June 2013
Pages	8

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CHANGE RECORDS			
Issue	Date	Description	Author
1.0	22/02/2013	First issue	Michele Scagliola
1.1	04/03/2013	Updated following comments from ESA.	Michele Scagliola
1.2	18/06/2013	Across-track antenna beamwidth at -3 dB updated to 1.1992 deg. Along-track antenna beamwidth at -3 dB updated to 1.06 deg.	Michele Scagliola

1 CryoSat footprints

In this paragraph, the beam-limited, the pulse-limited and the pulse-Doppler-limited footprints for CryoSat are discussed.

In the following table, the values of the various parameters used throughout the documents are listed.

Variable	Symbol	Value
Altitude of the satellite	h	730 km
Along-track antenna beamwidth at -3 dB	ϑ	1.06°
Across-track antenna beamwidth at -3 dB	ϑ	1.1992°
Speed of light	c	299792458 m/s
Compressed pulse length	τ	3.125 ns
Pulse bandwidth	B	320 MHz
Velocity of the satellite	v	7520 m/s
Pulse Repetition Frequency	PRF	18.181 kHz
Wavelength	λ	0.0221 m

Tab.1 Values of the parameters used throughout the document.

1.1 Beam-limited footprint

The beam-limited footprint is defined as the whole area on the Earth surface over which echoes are collected.

The beam-limited footprint depends mainly on the antenna illumination pattern, as a consequence it does not vary with the acquisition mode.

The beam-limited footprint can be described by its width in the along-track direction and in the across-track direction that depend on the antenna pattern. Being ϑ the antenna beamwidth at -3 dB and h the altitude of the satellite, the width of the beam-limited footprint results in

$$D = 2h \cdot \tan(\vartheta / 2)$$

where flat Earth approximation is assumed.

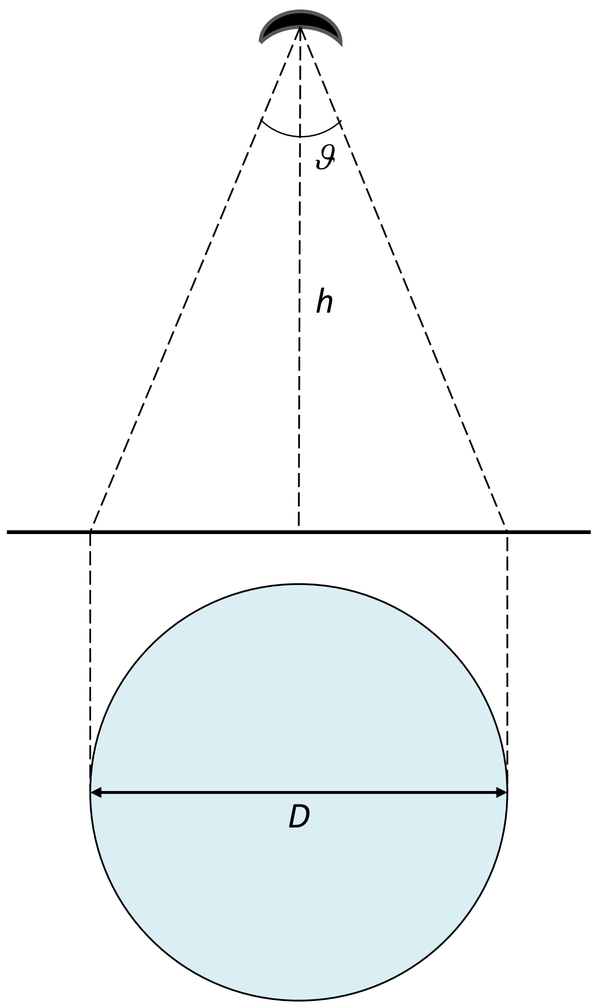

Fig.1 Beam-limited footprint: illumination geometry and footprint plan view.

Considering an average altitude of 730 km, $\vartheta = 1.06°$ in along-track and $\vartheta = 1.1992°$ in across-track, the beam-limited footprint for SIRAL can be decomposed in

- width of the beam-limited footprint in along-track approximately equal to 13.5 km
- width of the beam-limited footprint in across-track approximately equal to 15.3 km

Both the along and across beam-limited footprints are not constant but are dependent of the orbit characteristics and therefore they change with latitude (see figures below). The width of the beam-limited footprint in along track varies between 13.2 and 14.0 km while the beam-limited footprint in across track varies between 14.9 and 15.8 km.

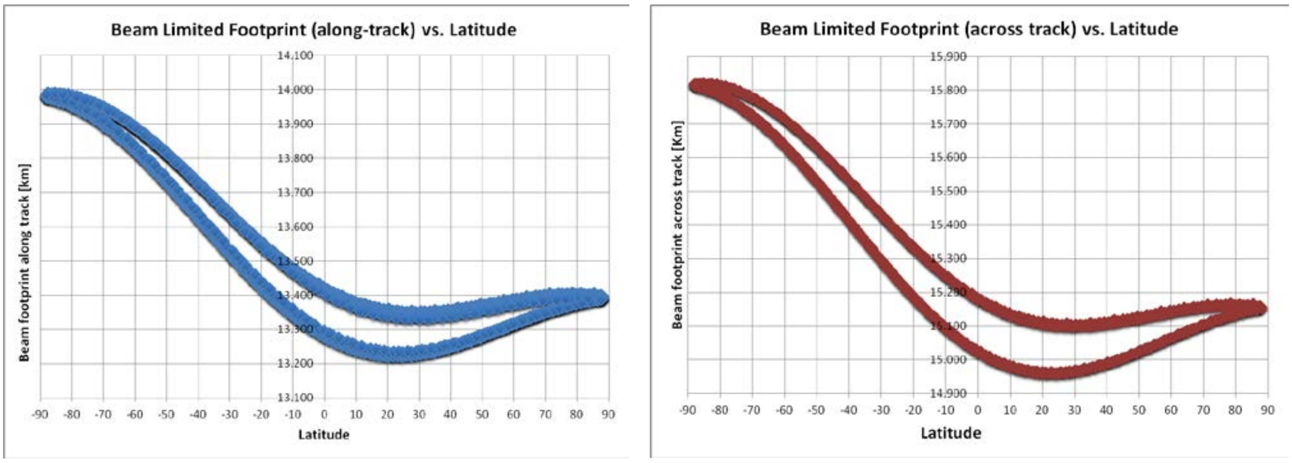

Fig.2 Beam-limited footprints vs Latitude.

1.2 Pulse-limited footprint

The pulse-limited footprint is defined as the illuminated area on ground around the point of closest approach and it corresponds to the area illuminated by the leading edge of the pulse until the time the trailing edge first intersects the surface.

In case of LRM, the pulse-limited footprint depends only on the compressed pulse duration, since LRM acquisition has only one independent variable (the time delay).

The Doppler beam formation in SAR/SARin allows to discriminate the direction of arrival of the echoes in the along-track direction, so that a pulse-Doppler footprint can be defined. This is due to the fact that in SAR/SARin there are two independent variables, the along-track position and the across-track position, related to time delay.

The width of the footprints for LRM and SAR/SARin are defined in the following using the flat Earth approximation and assuming a *quasiflat* surface on ground.

1.2.1 Pulse-limited footprint for LRM

In conventional altimeter acquisition, such as LRM, the area around the closest approach point is fully illuminated when the rear of the pulse reaches the Earth surface. As it is shown in the figure below, the pulse-limited footprint can be thus approximated as a circular area with radius equal to

$$r = \sqrt{h \cdot c \cdot \tau} = \sqrt{h \cdot \frac{c}{B}}$$

where c denotes the speed of light, h= 730 km is the average altitude of the satellite and the compressed pulse length is $\tau = 1/B$ with B is the pulse bandwidth.

For SIRAL, we have that the pulse-limited footprint has area approximately equal to 2.15 km^2 that corresponds to a width of the footprint approximately equal to 1.65 km.

The pulse-limited footprint has the same width in both the along-track and the across-track direction since in LRM there is only one independent variable that is the time delay.

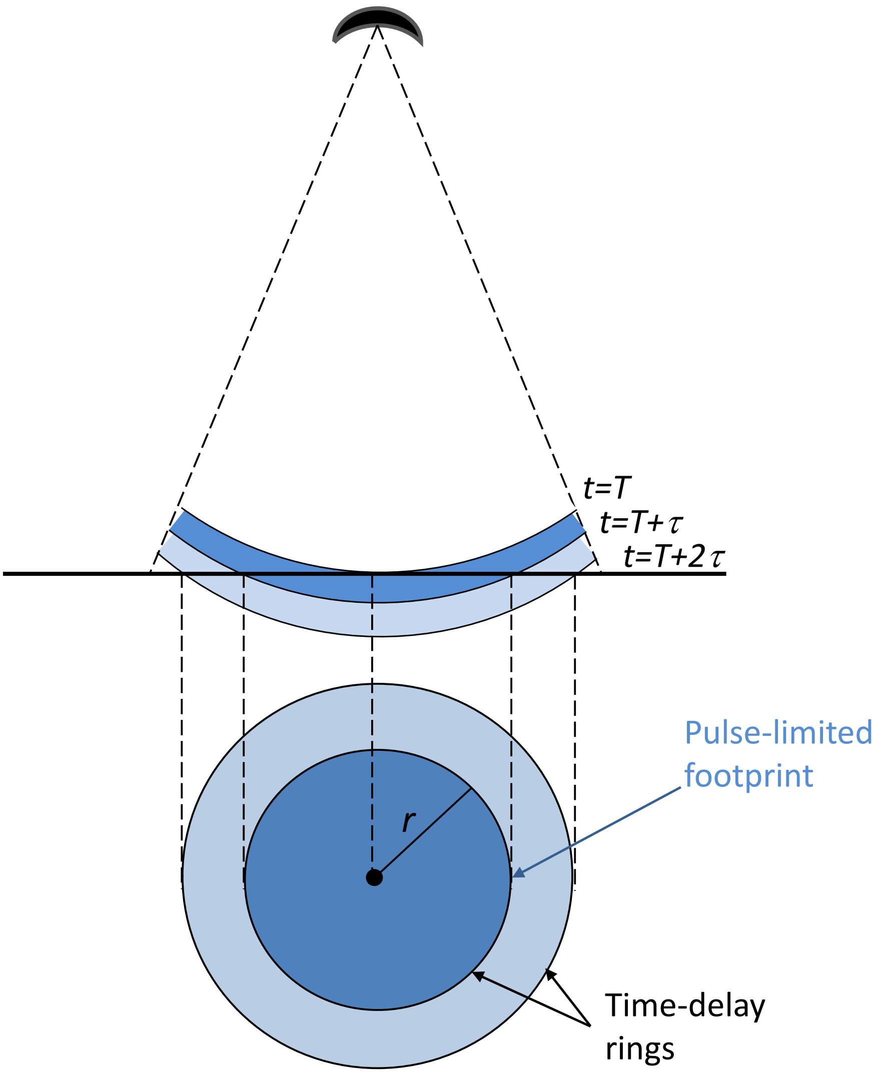

Fig.3 Pulse-limited footprint: illumination geometry and footprint plan view.

1.2.2 Pulse-Doppler-limited footprint for SAR/SARin

In SAR/SARin acquisition modes, the along-track processing allows to sharpen the footprint of the pulse in the along-track direction.

As stated before, the Doppler beam formation in SAR/SARin allows to discriminate the direction of arrival of the echoes in the along-track direction in addition to the measure of the time delay. This way the footprint width is defined independently in the two independent directions, the along-track and the across-track.

In the across-track direction, the footprint width for SIRAL is defined as the pulse-limited width in LRM. On the other hand, in the along-track direction, the footprint width for SIRAL is defined as the sharpened beam-limited footprint.

As depicted in the figure below, the pulse-Doppler-limited footprint for SAR/SARin can be approximated by a rectangle area given by the pulse-limited footprint width in the across track by the sharpened beam-limited footprint width in the along-track direction.

Since the band of Doppler frequencies that is unambiguously sampled by the *PRF* goes from *–PRF/2* to *+PRF/2*, and 64 different sharpened beams are equally spaced in the Doppler domain, the width of the sharpened beam-limited footprint results in

$$\Delta x = h \frac{\lambda}{2 \cdot N \cdot v} PRF$$

where h is the average altitude of the satellite, λ is the wavelength, v is the velocity of the spacecraft, R is the mean Earth radius and PRF is the Pulse Repetition Frequency.

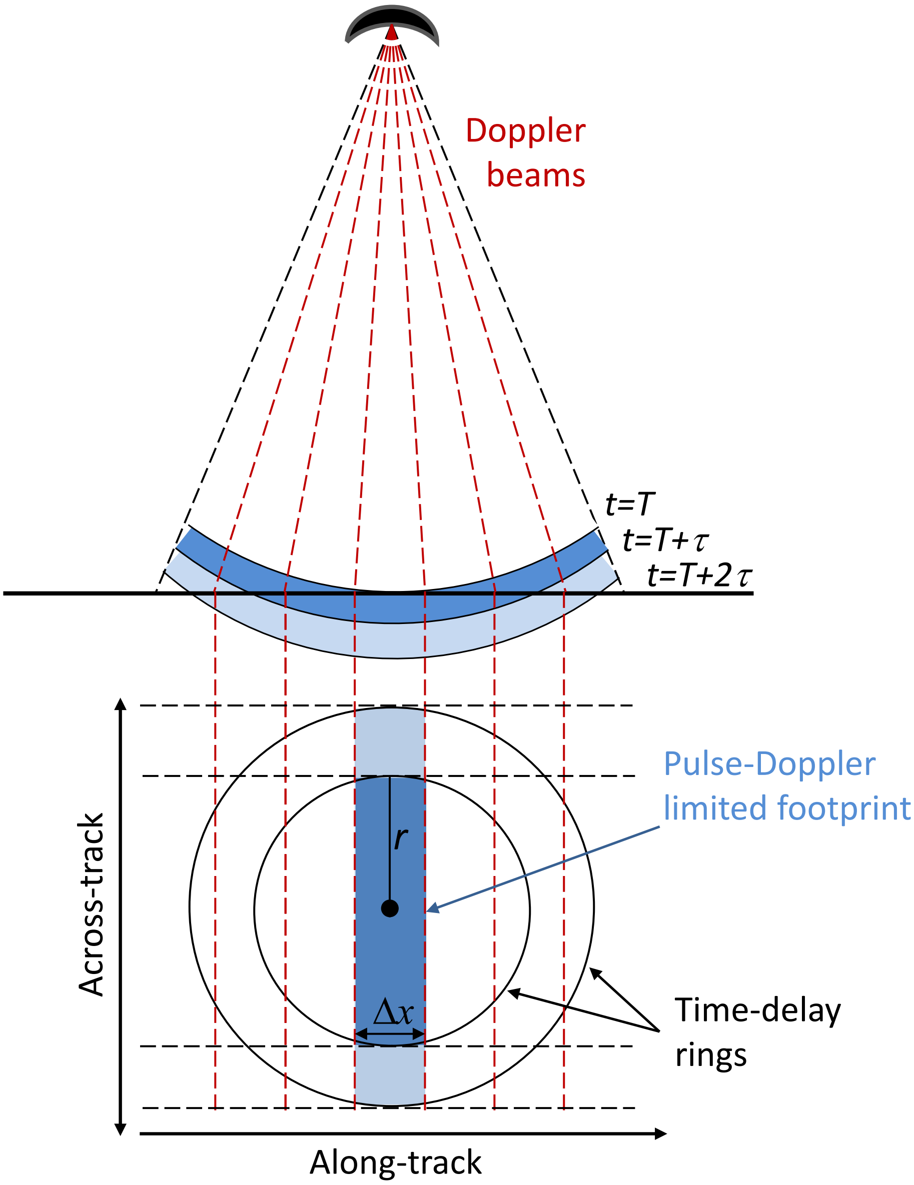

Fig.4 Pulse-Doppler limited footprint: illumination geometry and footprint plan view.

For CryoSat, the pulse-limited footprint width in the across track direction is approximately equal to 1.65 km while the sharpened beam-limited footprint width in the along-track direction is approximately equal to 305 m, that in turn corresponds to an along-track resolution approximately equal to 401 m[i], assuming flat Earth approximation. Hence, the pulse-Doppler-limited footprint for SAR/SARin results about 0.50 km^2.

[i] For more details on the along-track resolution, please refer to C2-TN-ARS-GS-5123.