SWOT and Sentinel 6 attitude laws

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1 Introduction

This document describes the theoretical attitude laws used in the orbit determination at CNES for satellites Sentinel 6 and SWOT.

2 Definition of the attitude frames

Orbital frame : this is the radial, tangential, normal frame, defined by the three vectors : R for the radial, N defined by $R \wedge V$ normalized, with V the inertial velocity, and $T = N \wedge R$. This frame depends only on the orbit (does not depend on the satellite attitude law).

Geodetic pointing frame : this frame is defined by a roll around T, then a pitch around the transformed N, and then a yaw around the transformed R. The final axes are named R_{sat}, T_{sat}, N_{sat}. The roll and pitch are small angles, they allow to transform the geocentric radial axis R axis to the geodetic radial axis R_{sat}.

The transformation matrix for coordinates from the satellite frame to the orbital frame, $\mathbf{R}$, is written as ($c_i = \cos\alpha_i$ and $s_i = \sin\alpha_i$) :

$$\mathbf{R} = \mathbf{R}_2\mathbf{R}_3\mathbf{R}_1 \tag{1}$$

$\mathbf{R}_2$ **:** roll around T

$$\mathbf{R}_2 = \begin{bmatrix} c_2 & 0 & s_2 \\ 0 & 1 & 0 \\ -s_2 & 0 & c_2 \end{bmatrix}$$

$\mathbf{R}_3$ **:** pitch

$$\mathbf{R}_3 = \begin{bmatrix} c_3 & -s_3 & 0 \\ s_3 & c_3 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$\mathbf{R}_1$ **:** yaw

$$\mathbf{R}_1 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & c_1 & -s_1 \\ 0 & s_1 & c_1 \end{bmatrix}$$

The figure 1 shows the definitions of the three angles α_1, α_2, α_3,

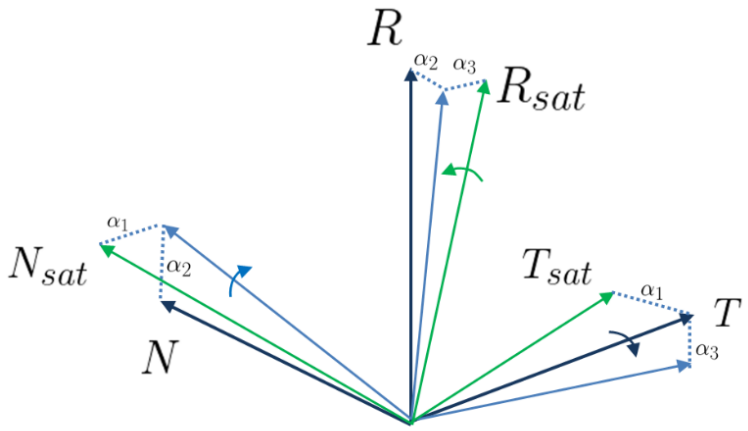

FIGURE 1 – Roll angle (α_2 around T), Pitch (α_3), Yaw (α_1)

The angles α_1, α_2, α_3 depend on the position of the satellite. With θ the position on the orbit, relative to the ascending node, the expressions are :

$$\begin{array}{lcll} \alpha_2 & = & a_2 \sin\theta & \text{roll angle} \\ \alpha_3 & = & a_3 \sin 2\theta & \text{pitch angle} \\ \alpha_1 & = & a_1 \cos\theta & \text{yaw angle} \end{array}$$

For Sentinel 6 the values used for the theoretical attitude law are (values in degrees) :

$$\begin{array}{lcr} a_2 & = & -0.111 \\ a_3 & = & 0.138 \\ a_1 & = & 4.225 \end{array}$$

Sentinel 6 attitude law coefficients

For SWOT the values used for the theoretical attitude law are (values in degrees), for the two orbit configurations :

$$\begin{aligned} a_2 &= -0.0707 \\ a_3 &= 0.1614 \\ a_1 &= 4.0526 \end{aligned}$$

SWOT attitude law coefficients, Fast Repeat Orbit

$$\begin{aligned} a_2 &= -0.0704 \\ a_3 &= 0.1607 \\ a_1 &= 4.0807 \end{aligned}$$

SWOT attitude law coefficients, Science Orbit

3 Satellite position in the Geodetic pointing frame

For Sentinel 6 the axes R_{sat}, T_{sat}, N_{sat} correspond to the platform axes, respectively $-z$, x, $-y$.

For SWOT the axes R_{sat}, T_{sat}, N_{sat} correspond respectively to the axes $-z$, x, $-y$ for the forward flying case. For the backward flying case, a 180 degrees rotation around R_{sat} is performed, the axes R_{sat}, T_{sat}, N_{sat} correspond respectively to the axes $-z$, $-x$, y.

4 SWOT solar array position

The Satellite reference frame, also called Observatory Reference Frame, is defined with the following elements :

Origin : the origin is at the center of the launcher interface ring at launch vehicle separation plane level

Z **axis :** perpendicular to the launcher interface and pointing to the earth.

Y **axis :** perpendicular to the payload radiator.

X **axis :** completes the frame. X is parallel to the solar array rotation axes. Depending on the beta angle, the velocity is along $-X$ for $\beta<0$ (flying backward) and $+X$ for $\beta>0$ (flying forward).

The figure 2 shows the Satellite Reference Frame, the Solar Array 1 is located on $+X$ face and the Solar Array 2 on $-X$ face.

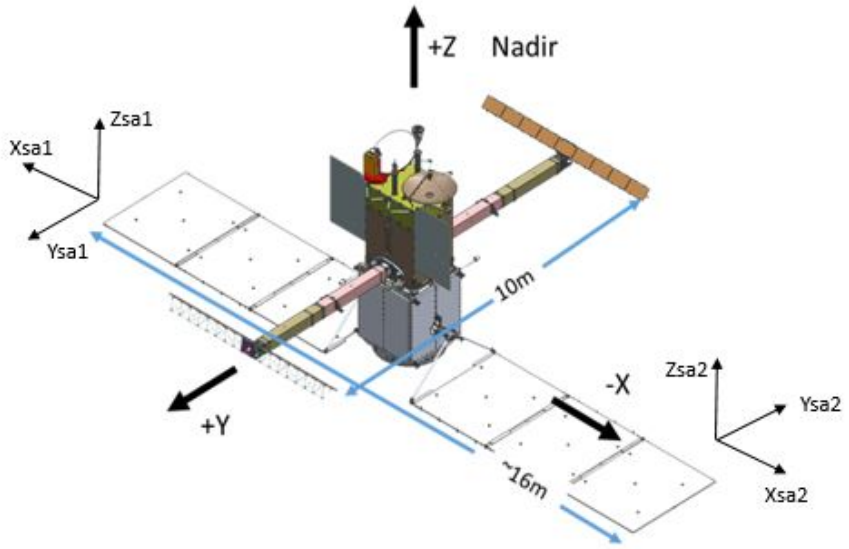

FIGURE 2 – SWOT Satellite Reference Frame

For each solar array, the cells are located on the surfaces oriented on the $-Z_{sa}$ direction : the normal to the cell surface is in $-Z$ direction for the canonical position corresponding to $\alpha = 0°$ ($-Z$, $-Z_{sa1}$, $-Z_{sa2}$ are identical).

For each Solar array, the rotation angle α around X_{sa} is oriented positively from Y_{sa} to Z_{sa}. The sun is always on the $-Y$ side. So the rotation angles of the solar array 1 ($+X$) are always negative and those of solar array 2 ($-X$) are always positive.

The angles can be approximately related to the beta angle in each solar array reference frame, using the information of the table 1

TABLE 1 – SWOT solar arrays pointing angle α

$\lvert beta \rvert$	Solar array 1 angle	Solar array 2 angle
$[0° - 6°]$	$0°$	$0°$
$[6° - 25°]$	-12°	$+12°$
$> 25°$	-30°	$+30°$