

# User Manual 4.1 Events: ground stations and satellites

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## Introduction

### Scope

Here are presented all the events detectors of the theme "stations and satellites".

## Javadoc

Those event detectors are available in the packages :

### Library

### Javadoc

Patrius [Package fr.cnes.sirius.patrius.propagation.event](#)

Patrius [Package fr.cnes.sirius.patrius.events](#)

The classes to build the stations models and satellites models are in the packages (and their sub-packages) :

### Library

### Javadoc

Patrius [Package fr.cnes.sirius.patrius.assembly](#)

Patrius [Package fr.cnes.sirius.patrius.groundstation](#)

## Links

None as of now.

## Useful Documents

None as of now.

## Package Overview

None as of now.

## Features Description

### g functions

This section describes the meaning of the g switching function for the "stations and satellites" event detectors :

#### ApparentElevationDetector

The g switching function computes the difference between the satellite apparent elevation  $\theta_{app}$  (the sum of geometrical elevation and refraction angle) and the threshold elevation  $\theta_{thr}$ .

This function is identical to the satellite elevation g function, except for the refraction angle term. The tropospheric correction refraction angle is computed according to Saemundssen formula quoted by Meeus.

#### ElevationDetector

The g switching function is the difference between the current elevation  $\theta_{satellite}$  and the threshold elevation  $\theta_{seuil}$ .

- $g < 0$  : the satellite is outside the cone delimited by the threshold elevation angle;
- $g > 0$  : the satellite is inside the cone.



## ExtremaElevationDetector

The `ExtremaElevationDetector` detects if the spacecraft is at a local extremum for the elevation. The choice of the extremum (maximum, minimum, or both) is done with the constructor, through the `elevationType` parameter.

The `g` switching function returns the elevation rate in the topocentric frame. An event occurs when the elevation rate is 0 meaning the satellite has reached an extrema. With  $P$  the satellite position,  $V$  its velocity and  $P_{proj}$ , the projection of the satellite position in the (X, Y) plane of the topocentric frame, the elevation rate is  $P_{proj} \cdot (P \cdot V) / (||P_{proj}|| \cdot ||P||)$ .

## GroundMaskElevationDetector

The `g` switching function computes the difference between the current elevation  $\theta_{sat}$  and the elevation for current azimuth interpolated from azimuth-elevation mask :  $\theta_{mask}(\alpha_{sat})$ . Since the  $\theta_{mask}$  term can be considered as the threshold angle, the ground mask elevation detector `g` function is identical to the elevation detector function.

## VisibilityFromStationDetector

The `g` function is positive when the spacecraft is in the station's field of view, negative otherwise. The station is defined by its topocentric frame. A field of view of the `IFieldOfView` type, defined in that frame, must be given, or directly an array of azimuths and elevations to define the field as it is done in the `GroundMaskElevationDetector`'s constructor. A tropospheric correction (`TroposphericCorrection` interface) can be taken into account in the computation. Set that correction as "null" to ignore it.

The station sensor model must have been correctly defined, its target being the spacecraft's sensor model (please refer to the next section : "PATRIUS models for satellites and stations antennas").

## StationToSatMutualVisibilityDetector

The `g` function is positive when the spacecraft is in the station's field of view (same definitions as in the `VisibilityFromStationDetector` detector, with same use of a tropospheric correction, only for the sight from the station), AND the station is in the spacecraft's given sensor's field of view (same definition as in the `TargetInFieldOfViewDetector`), negative otherwise.

The spacecraft's sensor must have been correctly defined, its target being the station sensor model (please refer to the next section : "PATRIUS models for satellites and stations antennas").

A boolean set at construction allows the user to decide to take maskings into account or not. So if asked, the visibility is interrupted when an object is masking, computing it the same way as in the `[MIS_SENSORS_Home MaskingDetector]`.

## SatToSatMutualVisibilityDetector

The `g` function is positive when the main spacecraft (the one concerned by the orbit propagation that includes this detector) is the secondary one's given sensor's field of view AND the secondary spacecraft is in the main one's given sensor's field of view (both with the same definition as in the `TargetInFieldOfViewDetector`).

Each of the two sensors must have been correctly defined, with the other sensor being the main target (please refer to the next section : "PATRIUS models for satellites and stations antennas"). A boolean set at construction allows the user to decide to take maskings into account or not. So if asked, the visibility is interrupted when an object is masking, computing it the same way as in the [MIS\_SENSORS\_Home MaskingDetector].

## **RFVisibilityDetector**

This detector computes the link budget between the ground station antenna and the satellite antenna and compares it to a threshold value; the model representing the RF link budget (RFLinkBudgetModel class) must be known by the detector in order to perform this computation (see the [SPC\_LINKBUDGET\_Home Link budget properties and models page]).

The g switching function is positive when the link budget is bigger than a threshold value; the threshold value is chosen by the user as it is an input parameter of the detector.

## **Focus on visibility detection**

### **PATRIUS models for station and satellite antennas**

The VisibilityFromStationDetector, StationToSatMutualVisibilityDetector and SatToSatMutualVisibilityDetector detectors use the PATRIUS ground station antennas and satellite antennas models. Here is a short description of them.

For more details, please refer to the specific pages (mainly in the Spacecraft user manual).

#### **Station antennas**

For advanced use of stations antennas, the GeometricStationAntenna or RFStationAntenna objects are used (package fr/cnes/sirius/patrius/groundstation).

The GeometricStationAntenna is defined by :

- its topocentric frame (see the [FDY\_FRAME\_Home frames page]);
- its field of view expressed in the topocentric frame (see the [SPC\_FIELD\_mainPage fields of view page]).

The RFStationAntenna is defined by :

- its topocentric frame;
- its specific parameter for RF Link Budget computations;
- no limitation of the field (no mask, no field of view). It can be limited by the RF parameters.

For detection of simple visibility events, not depending on satellite attitude, these objects are not necessary (use ElevationDetector, ApparentElevationDetector, or GroundMaskElevationDetector).

#### **Satellite antennas**

A generic satellite antenna should be represented by a Part of an assembly. One or more properties can be added to this Part to model its physical and/or geometrical features.

The SensorProperty can be added to a satellite antenna in order to simulate the mutual visibility among antennas; it must contain at least a "main field of view", that will be used for all the computations.

The SensorProperty is used by a SensorModel of the [SPC\_Home assembly]), which contains the

algorithm to compute the antennas visibility.

Once a `SensorModel` built, the proper target must be set, using the "setMainTarget" method :

- For the station-satellite mutual visibility, the station model, that is a `PVCoordinatesProvider`) must be set as this main target.
- For satellites mutual visibility, the `SensorModel` of the other satellite must be set as this main target, for both of them.

The `RFAntennaProperty` is used to set some RF features to a satellite antenna, when computing an RF link budget.

### **Detection of satellite/ground station visibility events**

The `VisibilityFromStationDetector` and `StationToSatMutualVisibilityDetector` both use the same description of a station antenna.

Both have two constructors :

- One that needs a `GeometricStationAntenna` object to define the station (frame and field of view)
- One that directly needs a topocentric frame, and an azimuth/elevation array. Internally, this one works as the first: it creates a field of view from the azimuth/elevation array. It is juste more simple to use.

A tropospheric correction can be considered when computing the visibility; in this case, the user should use the classes implementing the `TroposphericCorrection` interface (in the package `fr/cnes/sirius/patrius/signalpropagation`). When using a tropospheric correction, the temperature, moisture and pressure parameters of the station must be, if necessary, coherent with the considered station in the given tropospheric model.

### **Detection of mutual satellites visibility events**

The class `SatToSatMutualVisibilityDetector` contains the algorithme to detect satellites mutual visibility events; to use it, apply the following instructions:

- The detector is added to one of the spacecraft's propagator: this spacecraft becomes the "main" one;
- Each spacecraft is built out of an `Assembly` object and associated to a `SensorProperty/SensorModel` construction that represents its antenna;
- The secondary spacecraft's propagation is made in the detector, lead by the main one, to compute its `SpacecraftState` at each time step. The user shall provide a fully parametered propagator for him in order to do so, and give it at the detector construction;
- If the maskings computation is wanted, all potentially masking objects set in both sensor models will be tested at each time step. No need to set the same masking object to both : they would be tested twice.

### **Detection of RF visibility events**

The class `RFVisibilityDetector` contains the algorithme to detect ground station/satellite RF visibility events. The ground station antenna is represented by a `RFStationAntenna` class and the satellite antenna is represented by a Part of an assembly with `RFAntennaProperty`.

See the [SPC\_LINKBUDGET\_Home Link budget properties and models page] for more details on the parameters of the station antenna, the satellite antenna and for the link budget computation algorithme.

It is **NOT** possible to use `RFAntennaProperty` for RF LinkBudget computations between two satellites. Only the geometrical aspect (using a `Sensor Model`) is available.

## Getting Started

### Detection of satellite/ground station visibility events

Here is a code sample to create properly a mutual station/satellite visibility detector:

```
// tropospheric correction
//=====
// pressure (millibars)
final double pressure = 1020;
// temperature (celcius)
final double temperature = 20;
// moisture (percent)
final double moisture = 20;
// geodetic altitude (m)
final double altitude = 150;

final AngularCorrection correctionModel = new AzoulayModel(pressure,
temperature, moisture, altitude);

// station antenna model
//=====
// frame
final TopocentricFrame topoFrameStation = new TopocentricFrame(earth, point,
"Gstation");
// field of view
final String nameStationField = "circularStationField";
final IFieldOfView stationField = new CircularField(nameStationField,
FastMath.PI / 8., Vector3D.PLUS_K);
// ground station
final GeometricStationAntenna stationModel = new
GeometricStationAntenna(topoFrameStation, stationField);

// spacecraft sensor model
//=====
// We assume here that an assembly has been built, with a sensor property on
this "sensorPart" part.
// model creation
final SensorModel spacecraftSensorModel = new SensorModel(assembly,
sensorPart);
// target adding (the antenna is here considered ponctual)
spacecraftSensorModel.setMainTarget(stationModel, new
ConstantRadiusProvider(0.));

// detector creation
//=====
// the "false" boolean set here indicates that no masking will be computed
```

```
final EventDetector detectorMainPart = new
StationToSatMutualVisibilityDetector(
    spacecraftSensorModel, stationModel, correctionModel, false,
maxCheck, threshold);
```

### **Detection of mutual satellites visibility events**

Here is a code sample to create properly a mutual satellite /satellite visibility detector:

```
// We assume here that TWO assemblies have been built (main and secondary),
with a sensor property
// on each of them, on their "mainSpcSensorPart" and "secondarySpcSensorPart"
part.

// sensor models (the order of those operation is important !)
//=====
// main spacecraft model creation
final SensorModel mainSpcModel = new SensorModel(mainAssembly,
mainSpcSensorPart);
// secondary spacecraft model creation
final SensorModel secondarySpcModel = new SensorModel(secondaryAssembly,
secondarySpcSensorPart);
// target addings (the antennas are here considered ponctual)
mainSpcModel.setMainTarget(secondarySpcModel, new
ConstantRadiusProvider(0.));
secondarySpcModel.setMainTarget(mainSpcModel, new
ConstantRadiusProvider(0.));

// propagators
//=====
// We assume here that TWO propagators avec been created (main and
secondary),
// and that the secondary one is here fully parametered (forces, initial
state... but NO event detector !!)

// detector creation and adding
//=====
// the "false" boolean set here indicates that no masking will be computed
final EventDetector detector = new
SatToSatMutualVisibilityDetector(mainSpcModel,
    secondarySpcModel , secondaryPropagator, false, maxCheck,
threshold);

mainPropagator.addEventDetector(detector);
```

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Interface	Summary	Javadoc
EventDetector	This interface represents an event finder.	<a href="#">EventDetector</a>
LocalRadiusProvider	Provider for local radius.	<a href="#">LocalRadiusProvider</a>

## Classes

Class	Summary	Javadoc
ApparentElevationDetector	This class handles satellite apparent elevation (apparent raising and setting for a terrestrial viewpoint) events.	<a href="#">ApparentElevationDetector</a>
ElevationDetector	This class handles satellite elevation (raising and setting for a terrestrial viewpoint) events.	<a href="#">ElevationDetector</a>
ExtremaElevationDetector	This class handles events representing the reaching of the minimal or maximal elevation in a given topocentric frame (local frame of a station).	<a href="#">ExtremaElevationDetector</a>
GroundMaskElevationDetector	This class handles satellite elevation (raising and setting for a terrestrial viewpoint) events with respect to an azimuth-elevation mask.	<a href="#">GroundMaskElevationDetector</a>
VisibilityFromStationDetector	This class handles events representing the satellite apparent entering in a station's field of view.	<a href="#">VisibilityFromStationDetector</a>
SatToSatMutualVisibilityDetector	This class handles events representing the mutual visibility between two spacecraft's sensors.	<a href="#">SatToSatMutualVisibilityDetector</a>
StationToSatMutualVisibilityDetector	This class handles events representing the mutual visibility between a spacecraft's sensors and a station antenna.	<a href="#">StationToSatMutualVisibilityDetector</a>



RFVisibilityDetector	This class handles RF visibility events (when the link budget between a ground station antenna and a satellite antenna exceeds a threshold value).	<a href="#">RFVisibilityDetector</a>
Constant radius provider	Provider for constant radius body.	<a href="#">ConstantRadiusProvider</a>
Variable radius provider	Provider for variable radius body (ex: one axis ellipsoid).	<a href="#">VariableRadiusProvider</a>

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