Line of Sight

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Introduction

The Line of Sight constraint is concerned with the obstruction of the signal path (i.e., the path traveled by the signal from the transmitting object to the receiving object accounting for light time delay) by the ground, where the ground is modeled as an ellipsoid. The ellipsoid is considered as a fixed shape in the central body fixed frame. The ellipsoid models the ground as locally flat (i.e., no hills, nor mountains, nor valleys) and represents the simplest ground model possible. More accurate models of the ground require either an Az-El mask or the use of terrain—these effects are modeled by different Access constraints.

Obstruction Surface

The obstruction surface itself may be modeled in different ways by different STK objects (see Table 1). Typically, vehicles in STK use the central body ellipsoid shape itself as the obstruction surface. Facilities and Targets, however, model the obstruction surface by specifying the altitude of the ground itself (where altitude is measured either with respect to the central body ellipsoid or to mean sea level). An ellipsoid surface is constructed that passes through the specified altitude, has the same surface normal as the surface normal to the central body ellipsoid, and has the same shape type as the central body shape type (sphere, oblate spheroid, or tri-axial ellipsoid). This allows a user to better model the ground for a Facility located in Denver, Colorado, for example, where the ground is nominally a mile above the ellipsoid. The Rocky Mountains, of course, though visible from Denver aren't modeled at all by the Line of Sight constraint: an Az-El mask or terrain mask must be used to model local features of the ground.

Table 1: Ellipsoid models for different STK objects involved in an Access computation

STK Object	Ellipsoid Description
Facility, Target	Ellipsoid passes through the point specified by the ground altitude, having the same surface normal and shape type as the central body ellipsoid for object holding the constraint.
Satellite, Launch Vehicle, Missile, Aircraft	Central body ellipsoid for object holding the constraint
Ground Vehicle, Ship	Central body ellipsoid for object holding the constraint
Planet	The other object's central body ellipsoid
Star	The other object's central body ellipsoid
Area Target, Line Target	Central body ellipsoid for object holding the constraint
Radar, Receiver, Sensor, Transmitter	The model is taken from the parent object.

Special Considerations

Objects located underneath the obstruction surface

While the central body ellipsoid usually provides an adequate model for the local ground, there are places on the surface where it may not model the ground well. This is particularly true whenever the mean sea level is located significantly below the ellipsoid surface.

For this reason, the Line of Sight constraint (other than for Facilities and Targets) assumes that if an object is below the ellipsoid surface, it must be because the ellipsoid fails to model the ground well at that time. It believes that no object is intentionally modeled as being beneath its own ground model (since then it could never have access, a useless result). Thus, if an object is detected as being below the given ellipsoid surface, the ellipsoid surface is rescaled to put that object on the rescaled surface. The rescaled ellipsoid is then used as the obstruction surface.

Preferring one obstruction model over another

Often, both objects involved in an Access computation will have the Line of Sight constraint on. In some cases, only one Line of Sight constraint will be considered, not both.

- Stars. The Line of Sight constraint is not applied at all to Planets or other Stars.
- Planets. The Line of Sight constraint is not applied at all to Stars or other Planets. Furthermore, the Planet Line of Sight will be ignored if the other object's Line of Sight is on and its central body is the Sun.
- Aircraft, Launch Vehicle, Missile, and Satellite objects and their sub-objects. The Line of Sight constraint for these objects will be ignored if the other object has its Line of Sight on and the two objects have the same central body.

> NOTE: Stars use the scenario central body; Planets use the Sun.

As a consequence, an Access involving a Facility and a Satellite of the same central body will use the Line of Sight constraint as implemented by the Facility, ignoring the Satellite's obstruction model, when both objects have the Line of Sight constraint on. The intention is to prefer the use of the Line of Sight constraint for an object that is normally closer to the ground over that for objects that are normally above the ground.

Computing Obstruction

Obstruction occurs when the transmitted signal intersects the ellipsoid at some time during its travel along the signal path. The signal path is computed in an inertial frame F that is either a central body inertial frame or the solar system barycenter frame. The obstruction shape, however, moves in F because the shape is fixed in a central body fixed frame. The motion may consist of rotation and/or translation. The rotation of the central body fixed frame with respect to F causes the shape to rotate in F during signal transmission. If the obstructing central body is not the same central body used for F, then the obstructing central body translates in F during the signal transmission.

The difficulty in computing the obstruction of the signal stems from the need to convert to a common reference frame to do the computation. Either both the shape and location of the ellipsoid need to be modeled as time-varying in the inertial frame where the signal path is a straight line or the signal path needs to be transformed into a curved path in the fixed frame where the shape is fixed. Since it is simpler to model a curve rather than a volume, we choose to compute obstruction in the fixed frame where the ellipsoid surface remains constant.

Signal Path in the Fixed Frame

Let $\mathbf{R_A}$ and $\mathbf{R_B}$ locate the transmission and reception point, respectively, of the signal path in frame *F*. Let *t* be the time of transmission and $t+\Delta t$ be the time of reception, where Δt is the light time delay. The signal path in *F* is given by

$$\mathbf{s}(t+\tau) = \mathbf{R_A}(t) + \frac{\tau}{\Delta t}\left\{\mathbf{R_B}(t+\Delta t) - \mathbf{R_A}(t)\right\},\ 0 \le \tau \le \Delta t \tag{1.1}$$

Let $\mathbf{R_O}$ locate the obstructing central body with respect to *F*. Let M be the rotation matrix relating *F* to the fixed frame *E* of the obstructing central body. The signal path **w** in *E* is then:

$$\mathbf{w}(t+\tau) = M(t+\tau)\left[\mathbf{s}(t+\tau) - \mathbf{R_O}(t+\tau)\right] \tag{1.2}$$

Computing Obstruction: Ignoring signal motion along the path

When light time delay Δt is not considered (or just sufficiently small), then both *M* and $\mathbf{R_O}$ can be considered as constants, with the signal path in *E* then being a line segment. The appropriate model for obstruction in that case is the determination of whether that line segment intersects the ellipsoid at any point along its path.

Because an ellipsoid is a simple convex set, the intersection problem is simple to solve. Consider any point *P* in *E*. There exists a unique scale factor μ such that when all axes of the ellipsoid are scaled by this factor, the scaled ellipsoid passes through *P*. When $\mu>1$, *P* is outside the ellipsoid; $\mu=1$ indicates that *P* lies on the ellipsoid; and $\mu<1$ indicates that *P* is inside the ellipsoid. Given any line in *E*, there exists a scale factor μ such that the scaled ellipsoid is tangent to that line. Thus, for any line segment in *E*, the minimum value of μ for all points of that segment will occur at either an endpoint of the segment or at the tangency point if the tangency occurs within the line segment. So, by evaluating the value for μ at these three locations, one can determine μ_{min}, the minimum value of μ along the entire segment. Obstruction occurs if $\mu_{min}<1$.

Computing Obstruction: Modeling signal motion along the path

When the light time delay Δt is not sufficiently small, the signal should be modeled as traveling over the path in a finite time. Obstruction occurs if the signal $\mathbf{w}(t+\tau)$ ever lies inside the ellipsoid for some value τ^* between 0 and Δt.

This is more difficult to compute than the earlier case, because the signal path is not a straight line in *E*. We use an iterative procedure to determine τ^* by minimizing μ along the signal path in *E*. Obstruction occurs if $\mu_{min}<1$.