CARMA Memorandum Series #31

Collision Avoidance

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ABSTRACT

The positioning of the BIMA antennas in compact array configurations for CARMA introduces scenarios where collisions between adjacent antennas are possible. This document reviews these scenarios in a purely geometrical context, defining "exclusive regions" between adjacent antennas where only one will be allowed to traverse at a given time. These regions may be used to develop algorithms for moving antennas in a manner that will avoid collisions.

1. Introduction

In compact array configurations for CARMA, the BIMA antennas are positioned close enough where collisions between multiple antennas are possible. Given that the BIMA antennas could conceivably be controlled by two different sub-arrays, the chances for collisions increases significantly. The Collision Avoidance System will ensure that such collisions do not occur by identifying the possible collision scenarios and moving the antennas in a manner that will avoid them. By indentifying and preparing for collision scenarios ahead of time, we can minimize the number of false collisions that occur and reduce the amount of unnecessary slewing, thereby increasing time for observations.

2. Collision Scenarios

Collision scenarios may be defined using the geometry of the antenna (Fig. 1) and the position of the antenna in a given array configuration (Fig. 2). Although we have used the values for the antenna locations (Helfer 2004) in the E-array configuration in this memo, the final design will allow for modified or new array configurations in the future. The four types of collisions that may occur between adjacent antennas are subreflector-subreflector (Fig. 3), subreflector-dish (Fig. 5), dish-dish (Fig. 7), and subreflector-platform (Diagram not available because the tripod of the subreflector collides with a corner of the platform, and appropriate antenna AutoCAD diagrams were unavailable). Tripod collisions will not be separately considered because the dish or subreflector always protrudes further than the tripod legs; therefore when creating the exclusive regions, the tripod will always be within the limits set by the dish and subreflector. A list of the collision scenarios possible for each baseline is given in Table 2.

3. Collision Avoidance

To avoid the given scenarios, it is necessary to know which antennas can collide and the AZ/EL positions that will lead to each scenario. To accomplish this, each antenna will have lists of "neighboring", or adjacent, antennas as well as a list of "exclusive regions" for each neighboring antenna, corresponding to the four collision scenarios. We discuss these lists in further detail in this section, along with an explanation of how they will be used in determining paths of motion for the antennas.

3.1. Neighboring Antennas

From the antenna locations for a given configuration, each antenna will define a list of neighboring antennas for each collision scenario. Since it is possible for a neighbor to collide with a given antenna in more than one way (See Fig. 2), it may be included in multiple neighbor lists. Neighboring antennas will also be restricted to only those adjacent antennas where collisions are possible.

3.2. Exclusive Regions

To simplify the geometry, each component of the antenna that can be involved in a collision (ie, subreflector, dish, platform) will be represented by the locus of points from the pivot of the antenna to the finite extent of the component, with constraints taken for the movement of the components. For the subreflector, this is a sphere of radius 5.65m, the dish is a sphere of radius 4.65m, and the platform is a cylinder of radius 3.44m. These values include the standoffs with holding the hardware anticollision wires.

The intersection between these representations defines the collision scenarios for two neighboring antennas. Using these intersections, exclusive regions will be defined (with a small increase in size to account for the time delay in obtaining positional information for neighboring antennas).

From the exclusive regions, we can determine the corresponding AZ/EL using the specifications of the antenna. For subreflector collisions, this will be straightforward since the AZ/EL is determined using the axis from the pivot of the antenna through the subreflector. For dish collisions, we can find the axis through the subreflector using the axis from the pivot to the furthest extent of the dish. Furthermore, the computation for the exclusive regions and the AZ/EL conversions will be precomputed once at system startup.

3.3. Collision Avoiding Algorithm

The antenna will first obtain the path from one AZ/EL to another from the drive control. It will then get a list of exclusive regions that it will pass through while travelling along this path; this list will also be made accessible to all other antennas. If no exclusive regions are traversed, then the antenna will move to its new position; otherwise it will pass through each region using a traversing protocol:

- Obtain the positions of neighboring antennas, along with the exclusive regions that they will traverse
- Determine if it is the first antenna to the boundary of the region
  - if so, then traverse
  - it not, then wait until the neighbor has cleared the area, then traverse
- Update list of exclusive regions that will be encountered for the remainder of the path

The actual implementation of this algorithm will need to take into consideration explicit slew commands from the ACC as well as implicit slews resulting from track commands from the ACC when the antenna is not already on a source.

There are scenarios that exist where an antenna may be blocking an exclusive region indefinitely. Since a minimal impact on the drive control is desirable, for these scenarios, it will be necessary to stop all antennas and have the observer resolve the issue before allowing them to continue moving. There should be a "safe position" allowed for the antenna where all exclusive regions will be cleared once put into this position. These scenarios are as follows:

- An antenna that is in an exclusive region, but cannot be moved
- An antenna that is not sending information regarding its position to the ACC will block all of its exclusive regions

4. Open Questions

- Although it will not be the case for first light, will BIMA antennas in the E-array ever be used in two different scientific subarrays? (Allowing this will cause collision avoidance to become significantly more complicated)
- Each antenna must somehow obtain position information regarding its neighboring antennas. This may be accomplished via monitor points or with a separate CORBA server on the ACC (or via another mode)

REFERENCES

Helfer, Tamara T, *Version 2 CARMA Configurations for Cedar Flat* CARMA Memo 20 (2004)

Fleming, Matt, *Status of 6m Antenna Relocation* Sept 4 F2F Presentation (2004)

Antenna	X (m)	Y (m)
1	158.55	270.66
2	167.04	263.72
3	170.82	274.08
4	177.72	281.53
5	178.57	271.03
6	185.72	275.49
7	187.15	284.26
8	190.57	261.97
9	198.27	274.65

Table 1: Antenna positions in the E-array (Helfer 2004). Antenna numbers have been assigned here for following tables, but may not reflect the numbers assigned to the actual antennas.

Antenna 1	Antenna 2	Baseline (m)	SR-SR	SR-D	D-D	SR-P
1	2	11.00	X			
2	3	11.00	X			
4	5	10.50	X			
3	4	10.20	X	X		
4	6	10.00	X	X		
4	7	9.82	X	X		
6	7	8.89	X	X	X	
5	6	8.43	X	X	X	
3	5	8.33	X	X	X	X

Table 2: Antennas that may be involved in the various collision scenarios (SR = subreflector, D = dish, P = platform).

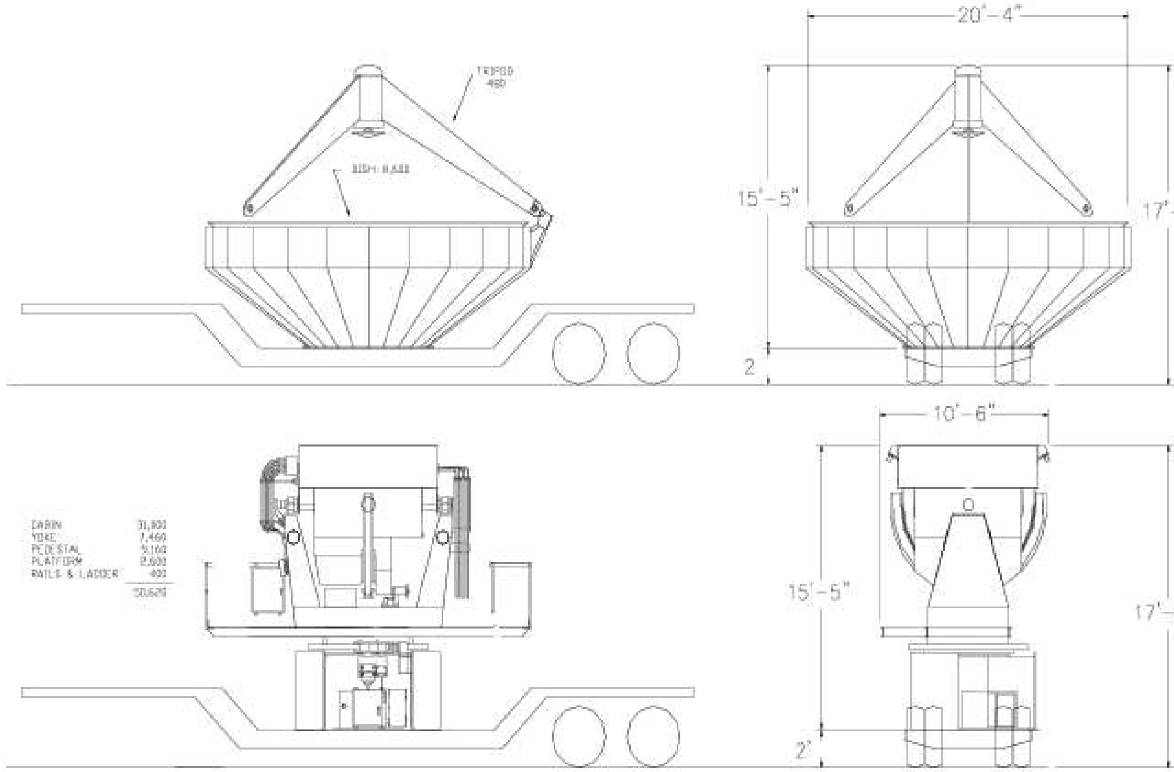

Fig. 1.— Schematic of the BIMA antenna. Dimensions are only given for some of the aspects of the antenna since the image was produced for the transport of the antennas from Hat Creek to Cedar Flat (Fleming 2004). Additional measurements were made by N.S. Amarnath to supplement those on this diagram.

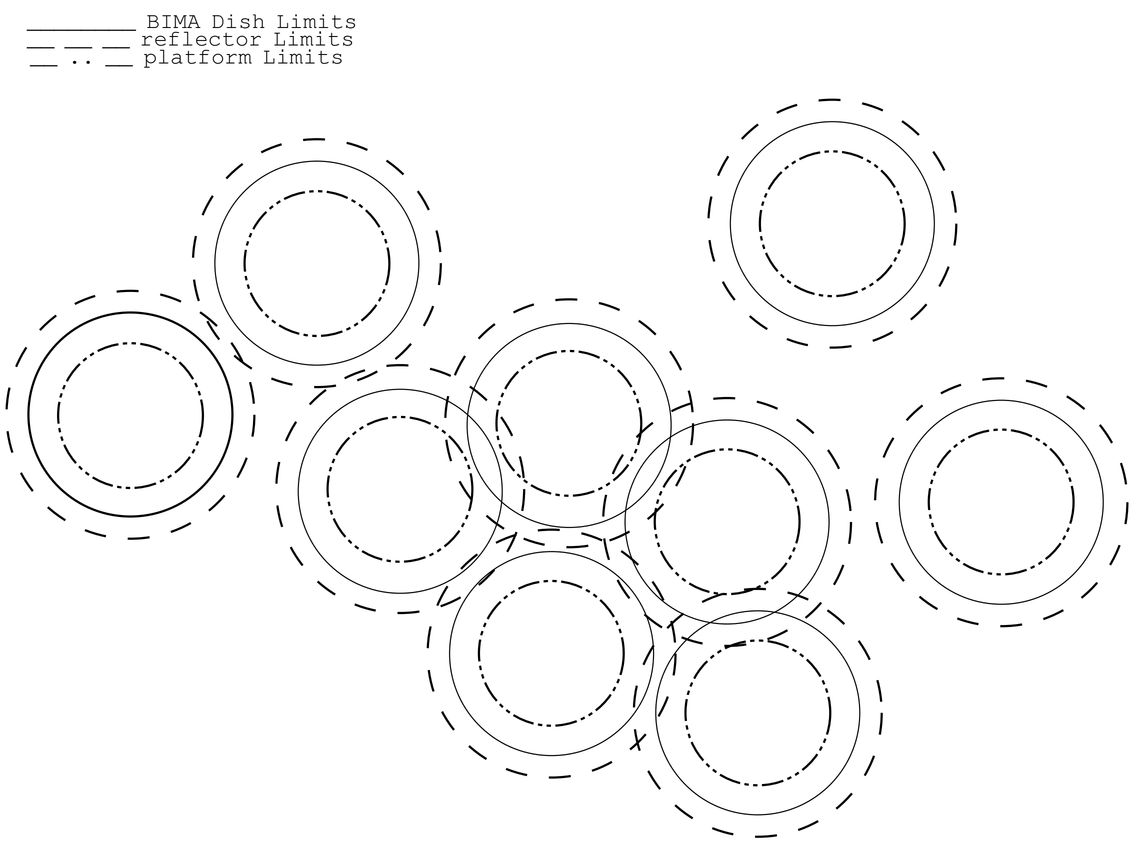

Fig. 2.— Top view of possible collisions between BIMA antennas, given their relative positions in the E-array configuration (Helfer 2004). The three types of lines represent the locus of points from the pivot of the antenna to the furthest extent for the three components involved in determining collisions (subreflector, dish, platform). Solid line represents the furthest extent that the dish can reach (9.3m), dashed line represents the outer limits that the subreflector can reach (diameter = 11.31m), the alternating dot-dashed line represents the limits that the platform will be able to reach (diameter = 6.59m).

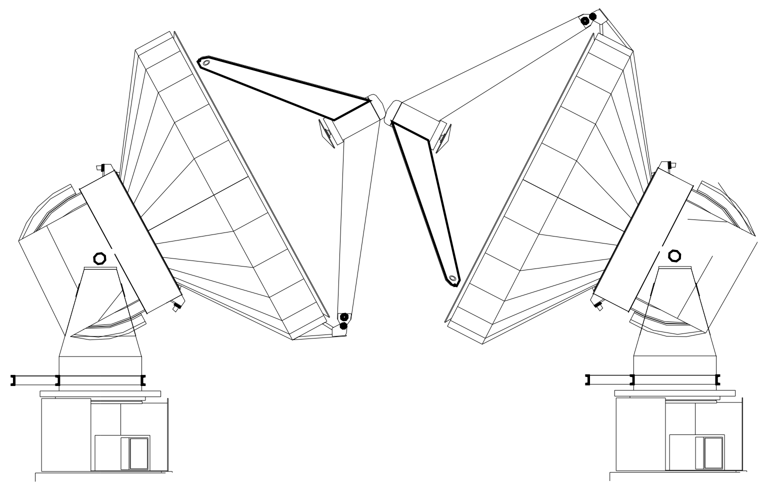

Fig. 3.— Schematic of subreflector colliding with another subreflector. Images modified from diagrams produced by Matt Fleming (Fleming 2004).

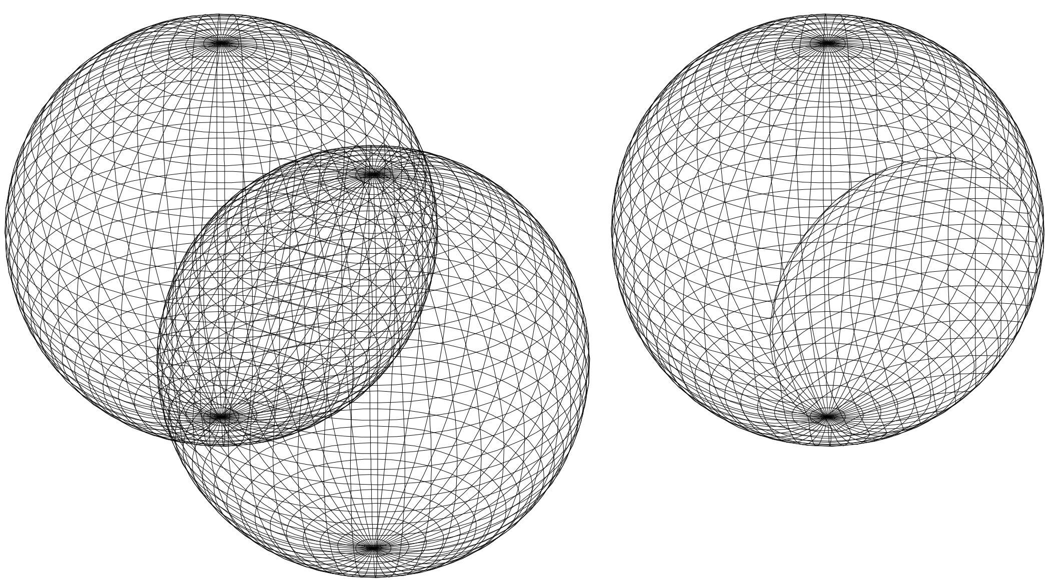

Fig. 4.— Exclusive region for subreflector-subreflector collision. Spheres represent locus of points from the pivot of the antenna to the furthest extent of the subreflector. Missing “area” represents the exclusive region.

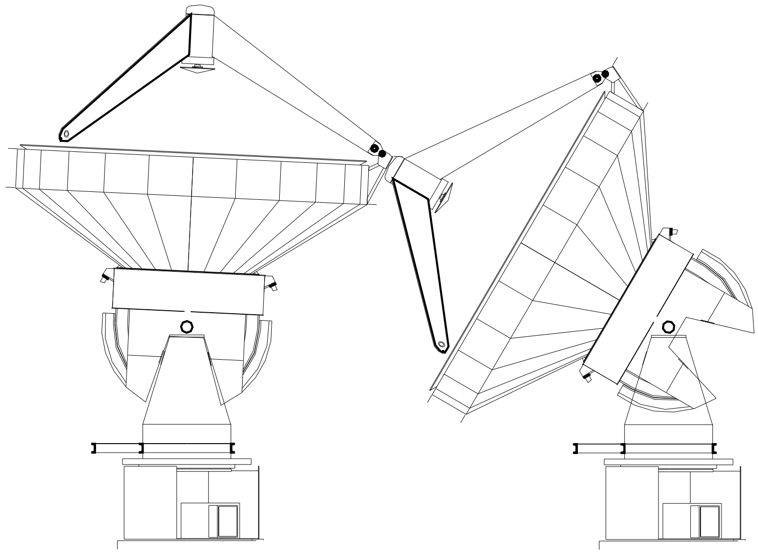

Fig. 5.— Schematic of subreflector colliding with a dish. Images modified from diagrams produced by Matt Fleming (Fleming 2004).

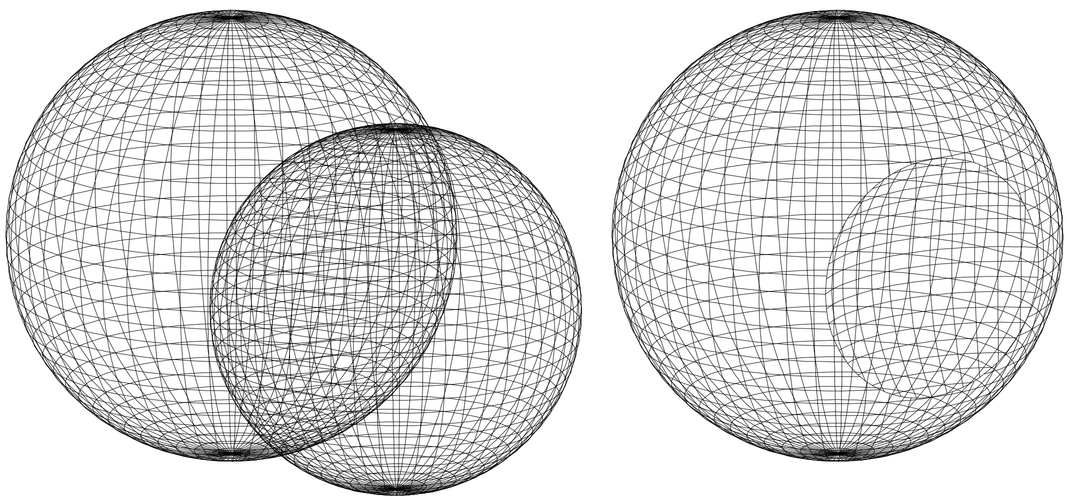

Fig. 6.— Exclusive region for subreflector-dish collision. The larger sphere represents locus of points from the pivot of the antenna to the furthest extent of the subreflector; the smaller sphere is to the furthest extent of the dish. Missing "area" represents the exclusive region. There exists a corresponding area on the smaller sphere.

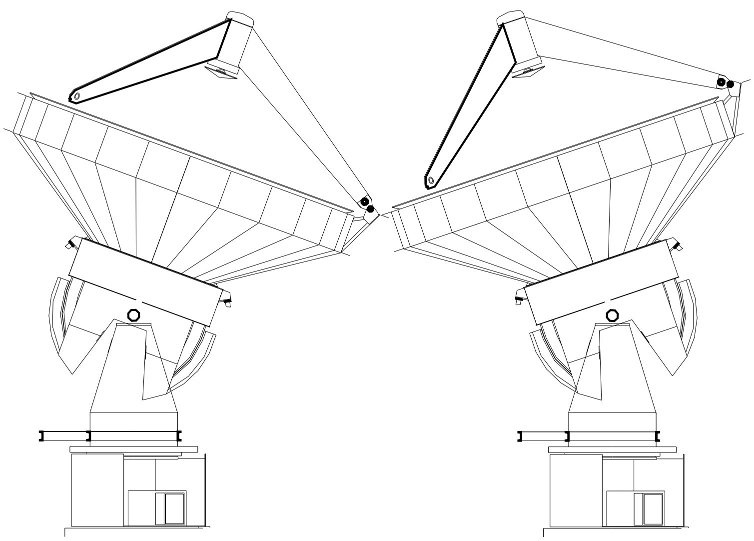

Fig. 7.— Schematic of dish colliding with an adjacent dish. The distance between the antennas has been set to 8.3m (the smallest baseline in the E-array). Images modified from diagrams produced by Matt Fleming (Fleming 2004).

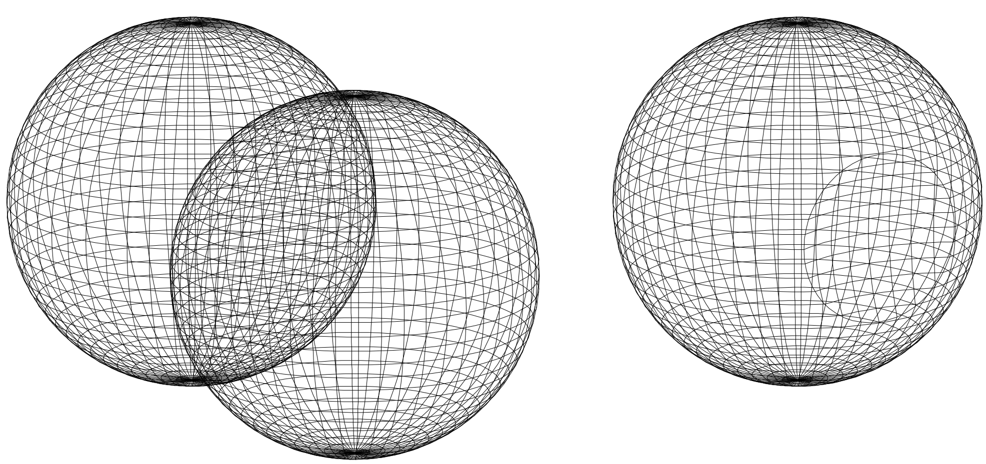

Fig. 8.— Exclusive region for a dish-dish collision, Spheres represent locus of points from the pivot of the antenna to the furthest extent of the dish. Missing "area" represents the exclusive region.

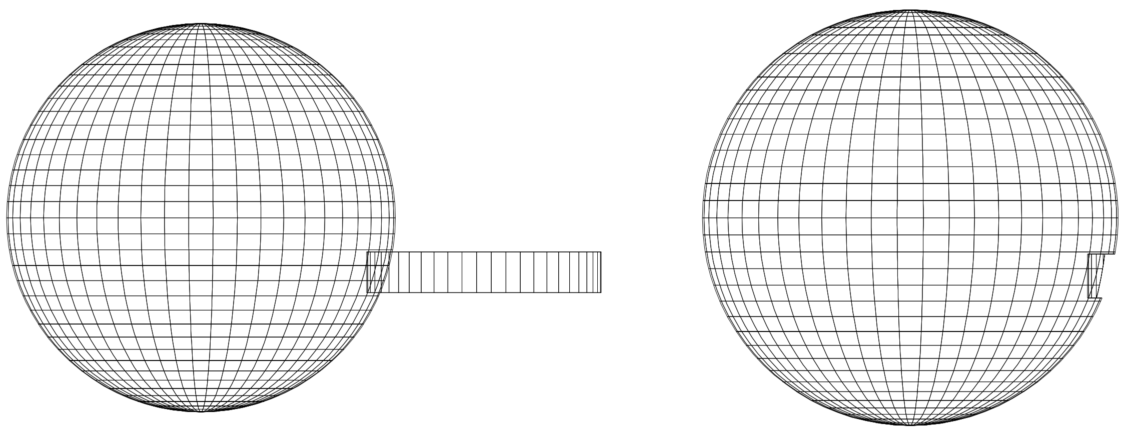

Fig. 9.— Exclusive region for subreflector-platform collision. Sphere represents the locus of points from the pivot of the antenna to the furthest extent of the subreflector; the cylinder is from the center to the corner of the platform. The missing "area" represents the exclusive region.