ATA GRASP Simulation Memo 2.0

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Abstract

This memo details the GRASP optical model of the ATA antennas including the presence of circular struts and the outer rim of the optics. The optical simulations use a hybrid mode conical feed pattern of aperture size 2.6λ and semi-flare angle $12.0°$ as detailed in the ATA GRASP Simulation Memo 1.0. Using the Solidworks file, I have been able to create an equivalent optical model of an ATA antenna by generating struts and the optical shield in GRASP.

1 Solidworks Model

Using the Solidworks model of the ATA, I have derived the coordinates of the struts, and specified the dimensions of the outer rim for both the primary and secondary reflector, this is given in Figure 1. By measuring the circular strut positions on both the primary and secondary reflectors, I have identified the dimensions of the strut positions in order to recreate them in GRASP, I have included the dimensions of the primary and secondary reflectors in Figures 2 and 3 respectively. The struts have a radius of 25.4 mm and are positioned in the centre of the outer rim of both the reflectors. The outer rim for the primary mirror has a width of 139.7 mm, whilst the secondary reflector outer rim is 185.0 mm wide.

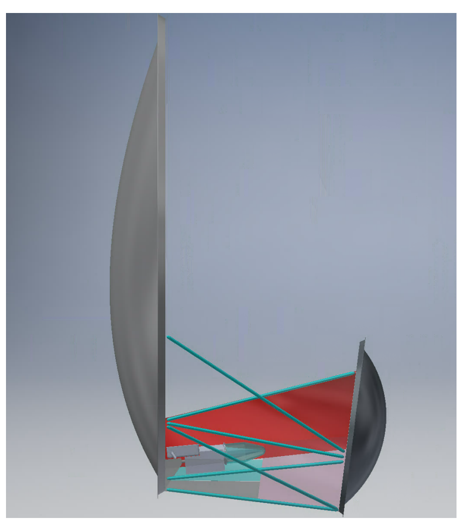

Figure 1: Side-profile ($x - z$ plane) view of the ATA Solidworks 3D model. The struts are highlighted in blue, and the metal shroud is in red.

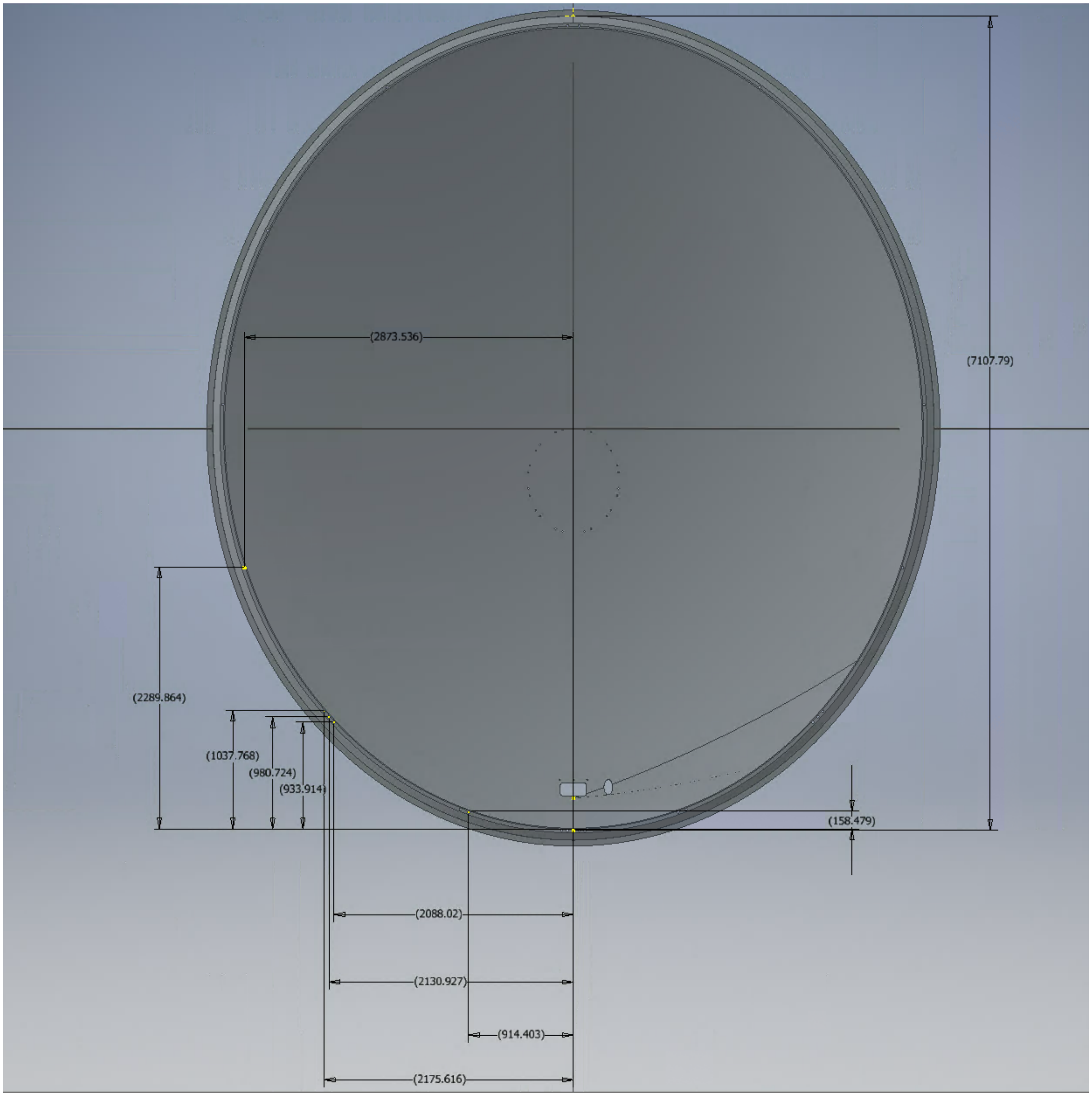

Figure 2: Front-view of the ATA Solidworks 3D model of the primary reflector. The dimension measurements indicate where the struts are to be placed in the GRASP 3D model.

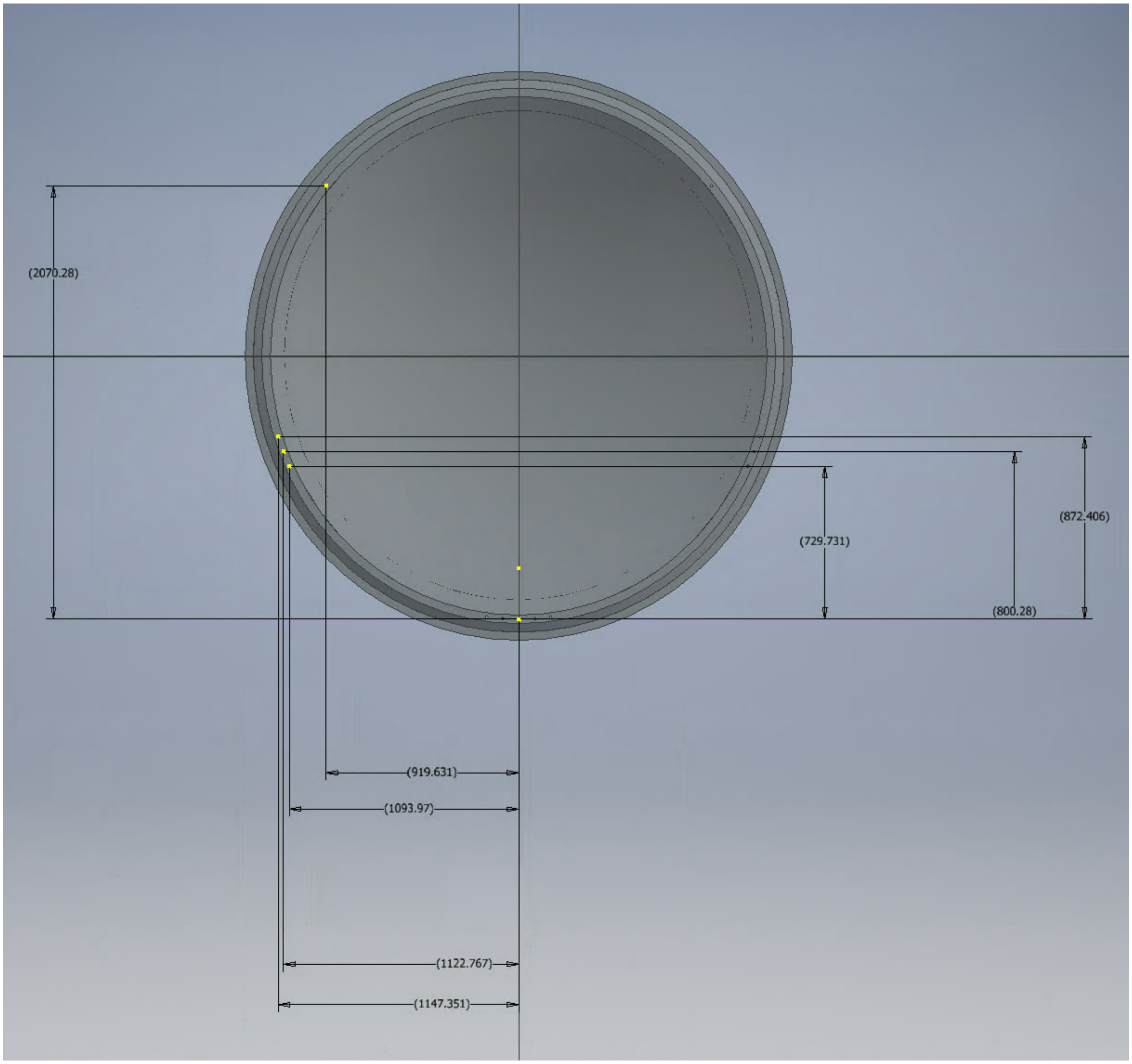

Figure 3: Front-view of the ATA Solidworks 3D model of the secondary reflector. The dimension measurements indicate where the struts are to be placed in the GRASP 3D model.

2 GRASP 3D Model

Using the dimensions of the struts and the outer rims from the Solidworks model, I created an equivalent model in GRASP by adding a flat circular reflector around both mirrors and generating a circular strut object. I defined a coordinate system at the position of the first strut, with the z-axis aligned to point from the base of the primary mirror to the base of the secondary. From this coordinate system I then defined all other struts in terms of their relative x, y and z coordinates. In Figure 4 I define the relative coordinates of the circular struts. Figure 5 shows the 3D model developed in GRASP complete with ray diagram.

To create the shroud, I used 15 triangular plate-surfaces to surround the outer rim defined by the struts. The positions of the triangular panels ensure that the reflectors are not blocked. Figure 6 shows the 3D model with the shroud.

	Point1 x	Point1 y	Point1 z	Point2 x	Point2 y	Point2 z
1	0.0 m	0.0 m	0.0 m	0.0 m	0.0 m	2.9 m
2	0.1404 m	0.917 m	0.0 m	0.729 m	1.16 m	2.8 m
3	0.1404 m	-0.917 m	0.0 m	0.729 m	-1.16 m	2.8 m
4	0.865 m	2.1285 m	-0.25 m	0.0 m	0.15273 m	2.9 m
5	0.865 m	-2.1285 m	-0.25 m	0.0 m	-0.15273 m	2.9 m
6	0.8999 m	2.174 m	-0.25 m	0.8 m	1.13 m	2.8 m
7	0.8999 m	-2.174 m	-0.25 m	0.8 m	-1.13 m	2.8 m
8	0.9448 m	2.21 m	-0.3 m	2.07 m	0.99 m	2.7 m
9	0.9448 m	-2.21 m	-0.3 m	2.07 m	-0.99 m	2.7 m
10	2.289 m	2.873+0.06 = 2.933 m	-0.65 m	0.872 m	1.15 m	2.8 m
11	2.289 m	-(2.873+0.06) = -2.933 m	-0.65 m	0.872 m	-1.15 m	2.8 m

Figure 4: The positions of the struts between the primary and secondary reflectors with respect to a coordinate system defined by the z-axis aligned to point from the base of the primary to the base of the secondary mirror.

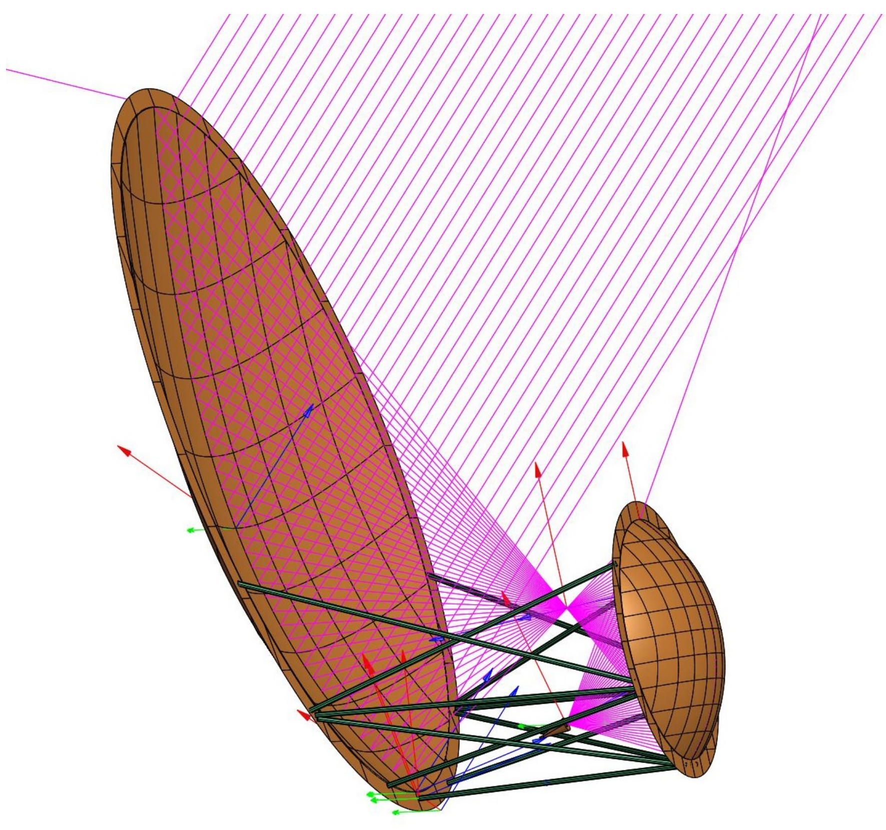

Figure 5: The 3D GRASP model of the ATA antenna including the struts and the shield around both the primary and secondary reflectors.

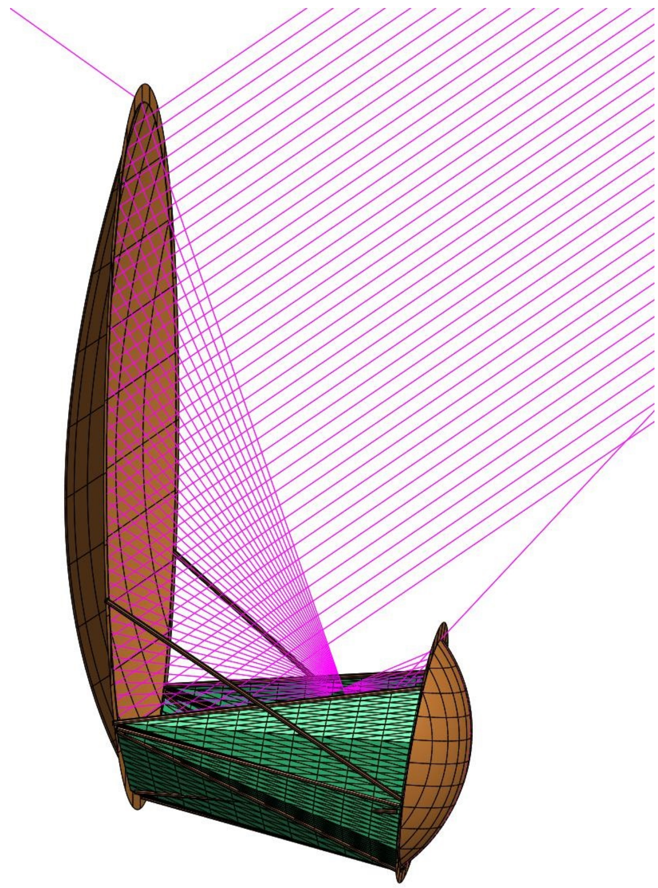

Figure 6: The ATA shroud defined by 15 triangular reflective panels highlighted in green. These will be modelled as a reflective surface.

3 Shield and Strut Modelling

To model the optical properties of the struts and the shield the correct GRASP commands must be used. These involve generating currents on each of the reflector surfaces and sending them to the sky cut, which generates the beam pattern. Below I list the commands that generate a correct standard beam pattern for an off-axis Gregorian:

1. **Get Currents** > Source: Feed, Target: Sub-reflector
2. **Get Currents** > Source: Feed + Sub-reflector, Target: Main-reflector
3. **Get Field** > Source: Main-reflector, Target: Sky cut
4. **Add Field** > Source: Feed + Sub-reflector, Target: Sky cut.

The resulting beam pattern for the above commands is given in Figure 9. Figures 7 and 8 show screen grabs of the commands used to generate the ATA GRASP simulations including the struts and the shields respectively. The corresponding beam patterns are given in Figures 10 and 11. Form these Figures, we can draw two important conclusions:

1. The struts do not cause any degradation to the main beam, however the spillover lobes become less smooth.

2. The shield surrounding the primary and secondary mirrors reduced sidelobes between $-90.0°$ and $90.0°$ degrees.

	Command Type	Objects	Arguments
1	Get Currents	Source : ata01_feed Target : ata01_sub_po	field_accuracy : -80.0 auto_convergence_of_po : on convergence_on_scatterer : ata01_main_reflector,circular_struts convergence_on_output_grid : ata01_cut convergence_on_expansion_grid : max_bisections : 5 integration_grid_limit : on obsolete_conv_on_po_grid :
2	Get Currents	Source : ata01_sub_po + ata01_feed Target : ata01_main_po	field_accuracy : -80.0 auto_convergence_of_po : on convergence_on_scatterer : circular_struts convergence_on_output_grid : ata01_cut convergence_on_expansion_grid : max_bisections : 5 integration_grid_limit : on obsolete_conv_on_po_grid :
3	Get Currents	Source : ata01_sub_po + ata01_feed + ata01_main_po Target : strut_analysis_circ_cross	field_accuracy : -80.0 auto_convergence_of_po : on convergence_on_scatterer : convergence_on_output_grid : ata01_cut convergence_on_expansion_grid : max_bisections : 5 integration_grid_limit : on obsolete_conv_on_po_grid :
4	Get Field	Source : ata01_main_po Target : ata01_cut	
5	Add Field	Source : ata01_feed + ata01_sub_po + strut_analysis_circ_cross Target : ata01_cut	

Figure 7: A snapshot of the commands used to generate the radiation pattern of the ATA with the struts included in the GRASP simulation.

	Command Type	Objects	Arguments
1	Get Currents	Source : ata01_feed Target : ata01_sub_po	field_accuracy : -80.0 auto_convergence_of_po : on convergence_on_scatterer : ata01_main_reflector,ata01_main_shield,ata01_sub_shield convergence_on_output_grid : ata01_cut convergence_on_expansion_grid : max_bisections : 5 integration_grid_limit : on obsolete_conv_on_po_grid :
2	Get Currents	Source : ata01_sub_po + ata01_feed Target : ata01_main_po	field_accuracy : -80.0 auto_convergence_of_po : on convergence_on_scatterer : ata01_main_shield,ata01_sub_shield convergence_on_output_grid : ata01_cut convergence_on_expansion_grid : max_bisections : 5 integration_grid_limit : on obsolete_conv_on_po_grid :
3	Get Currents	Source : ata01_sub_po + ata01_feed + ata01_main_po Target : ata01_sub_shield_po	field_accuracy : -80.0 auto_convergence_of_po : on convergence_on_scatterer : ata01_main_shield convergence_on_output_grid : ata01_cut convergence_on_expansion_grid : max_bisections : 5 integration_grid_limit : on obsolete_conv_on_po_grid :
4	Get Currents	Source : ata01_sub_po + ata01_feed + ata01_main_po + ata01_sub_shield_po Target : ata01_main_shield_po	field_accuracy : -80.0 auto_convergence_of_po : on convergence_on_scatterer : convergence_on_output_grid : ata01_cut convergence_on_expansion_grid : max_bisections : 5 integration_grid_limit : on obsolete_conv_on_po_grid :
5	Get Field	Source : ata01_main_po Target : ata01_cut	
6	Add Field	Source : ata01_feed + ata01_sub_po + ata01_main_shield_po + ata01_sub_shield_po Target : ata01_cut	

Figure 8: A snapshot of the commands used to generate the radiation pattern of the ATA with both the primary and secondary shields included in the GRASP simulation.

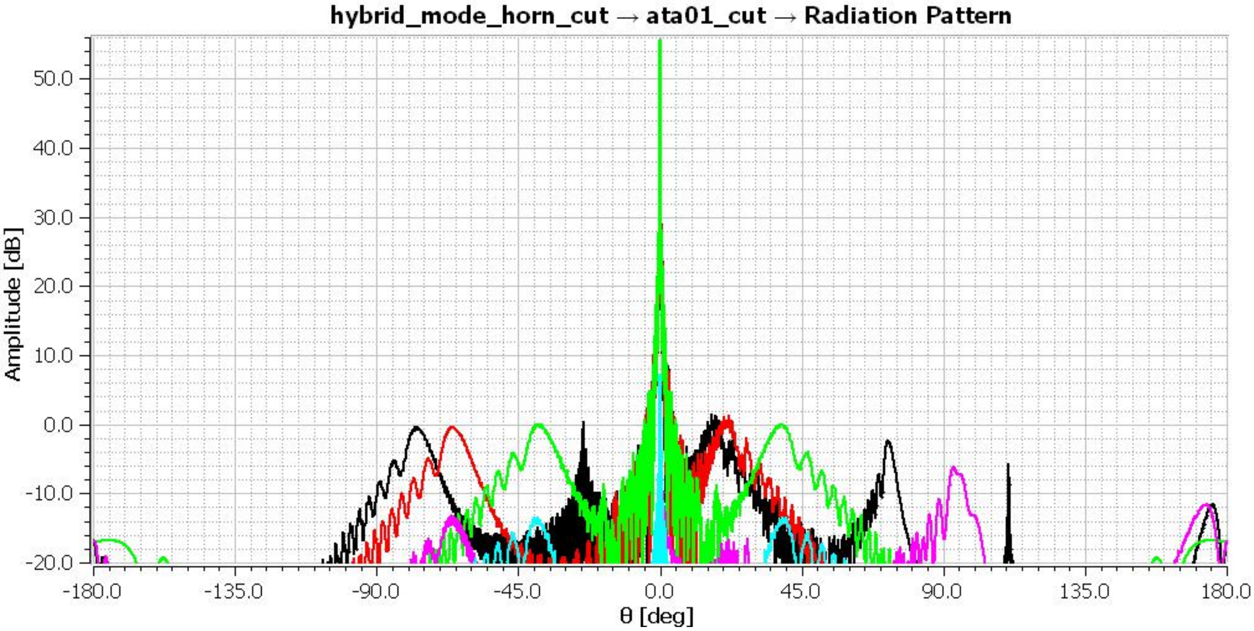

Figure 9: The radiation pattern of the optics without the struts, shield or shroud. *Black: co-polar beam* $\phi = 0.0°$, *red: co-polar beam* $\phi = 45.0°$, *green: co-polar beam* $\phi = 90.0°$, *pink: cross-polar beam* $\phi = 45.0°$, *cyan: cross-polar beam* $\phi = 90.0°$.

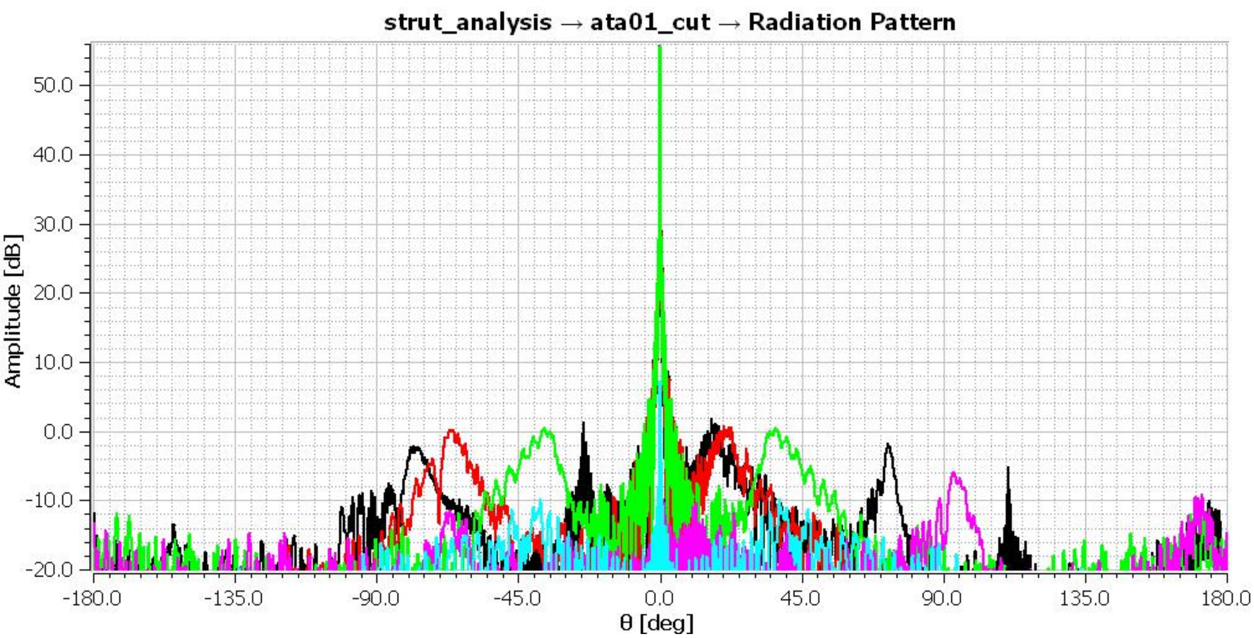

Figure 10: The radiation pattern of the optics with the struts. The struts cause higher residual power in the farthest angles, along with some deterioration of the sidelobe structure. *Black: co-polar beam* $\phi = 0.0°$, *red: co-polar beam* $\phi = 45.0°$, *green: co-polar beam* $\phi = 90.0°$, *pink: cross-polar beam* $\phi = 45.0°$, *cyan: cross-polar beam* $\phi = 90.0°$.

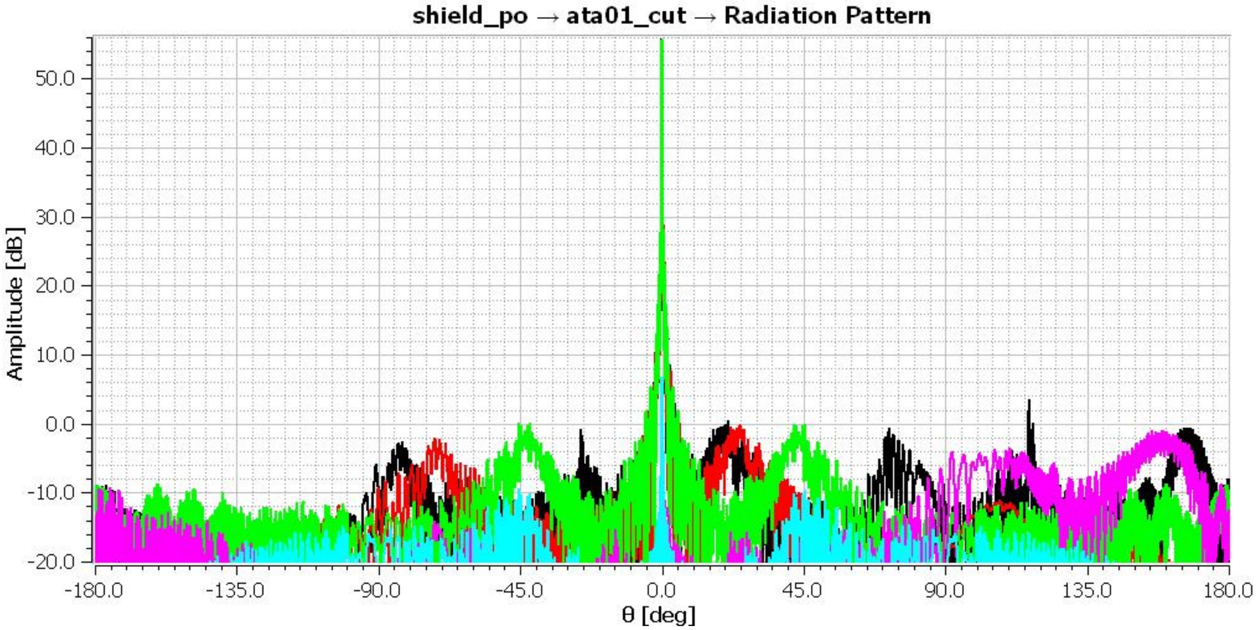

Figure 11: The radiation pattern of the optics with the shield. The additional rim around the primary and secondary reflectors has reduced the spillover lobes that appear between -90.0° and 90.0°. *Black: co-polar beam* $\phi = 0.0°$*, red: co-polar beam* $\phi = 45.0°$*, green: co-polar beam* $\phi = 90.0°$*, pink: cross-polar beam* $\phi = 45.0°$*, cyan: cross-polar beam* $\phi = 90.0°$*.*

4 Further Optical Modelling

The next stage in the optical simulations would require modelling of the shroud. This can be carried out in a similar procedure to the shield optical simulations, where the rays are set to converge on each of the triangular panels, and then sent to sky cut. In addition, it would be interesting to run a model including the struts, shield and the shroud. These simulations should be re-run with the true tabulated beam pattern of the feed horn designed for the ATA optics.