8-23 Small Reflector Splash Plate BOR-MoM Design

This section illustrates using the BOR-MoM code CHAMP (TICRA) for analysis and design through optimization of an axisymmetric 25λ diameter reflector using a Turrin horn feed and a 2.75λ diameter subreflector. Initial design uses a single displaced axis Gregorian reflector. The displaced axis reflector has a ring focus and the combination of caustic feeding and central hole causes high sidelobes. The program DAXSG computes the geometric parameters and generates spline input to CHAMP geometry.tor file. The following list is a parameters of the initial design.

```
Displaced axis Gregorian single offset dimensions

 Supplement to Modern Antenna Design by Thomas Milligan
 Main reflector focal length 200.2500
 Subreflector diameter:       82.5000
 Main diameter:              750.0000
 Feed half subtended angle:     52.00

 Effective f/D:         0.51258
 Focus Axis length:      17.538
 Main Vertex to feed:   182.712
 Feed to subreflect.:    25.100
 Main diameter:         750.000
 Main reflector depth:  139.062
 Subreflector dia:       82.500
 Vertex to subr. Top:   217.903
 Axis tilt:               66.97
 Feed subtended angle:   104.00
 Ellipse 2*C:            44.823
 Eccentricity:          0.66863

 Aperture distribution calculations

 Beamwidth =   104.00
 Edge Taper Spillover  Taper Loss   Total
    8.00     -0.595      -0.250    -0.845
    9.00     -0.466      -0.237    -0.703
   10.00     -0.366      -0.232    -0.597
   11.00     -0.288      -0.233    -0.521
   12.00     -0.227      -0.240    -0.467
   13.00     -0.179      -0.253    -0.432
   14.00     -0.142      -0.270    -0.412
   15.00     -0.112      -0.293    -0.405
   16.00     -0.089      -0.319    -0.408
   17.00     -0.071      -0.350    -0.420
   18.00     -0.056      -0.383    -0.439
   19.00     -0.044      -0.419    -0.464
   20.00     -0.035      -0.458    -0.494
```

The program COWSDT is used to generate 35 external corrugations along the feed tube by generating a geometry.tor file addition which modifies the "horn_external" section of the Turrin horn with a 0.62λ diameter aperture. The last two of the horn exterior are retained to extend it to the central reflector center hole.

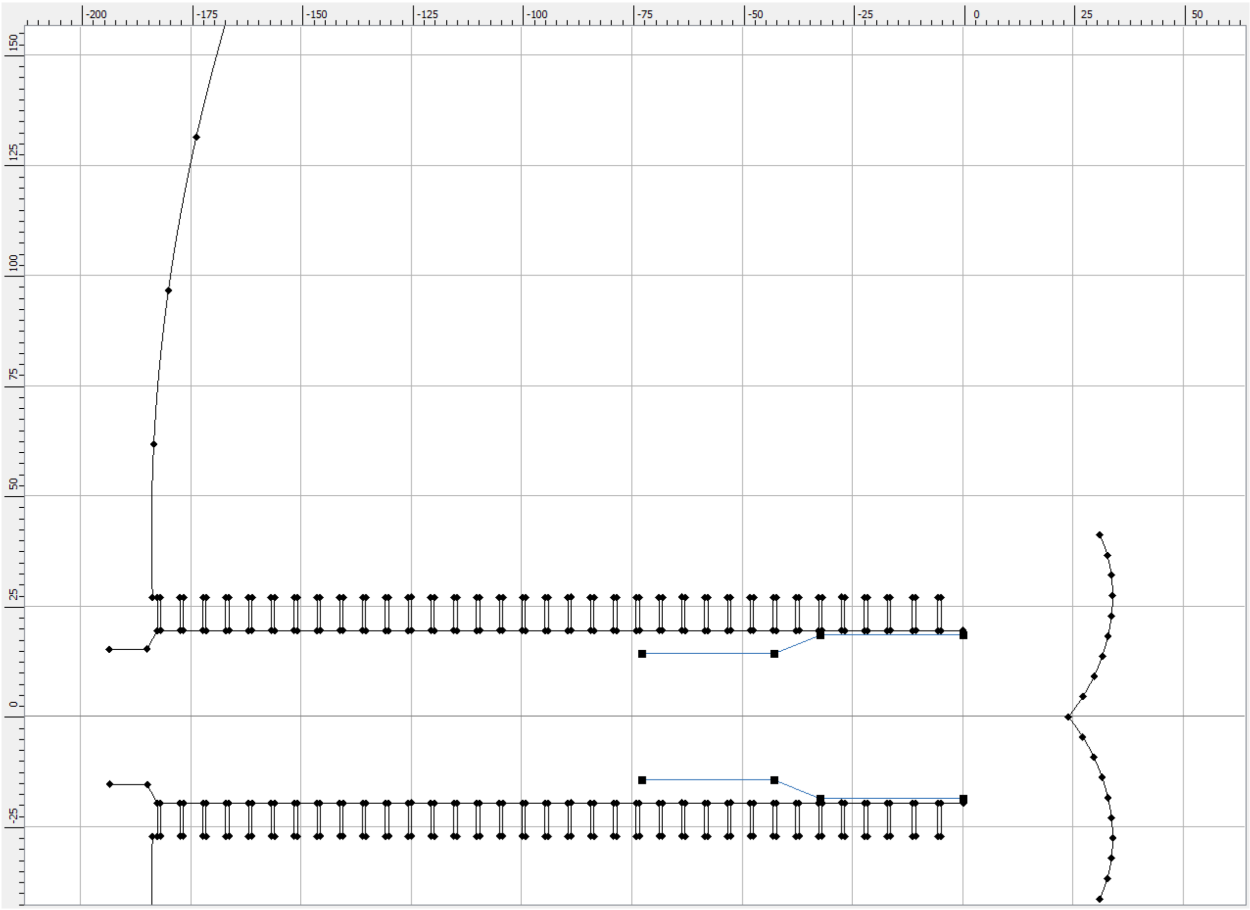

Figure 8-23.1 CHAMP geometry of initial feed tube, spline displaced axis subreflector, and spline main reflector

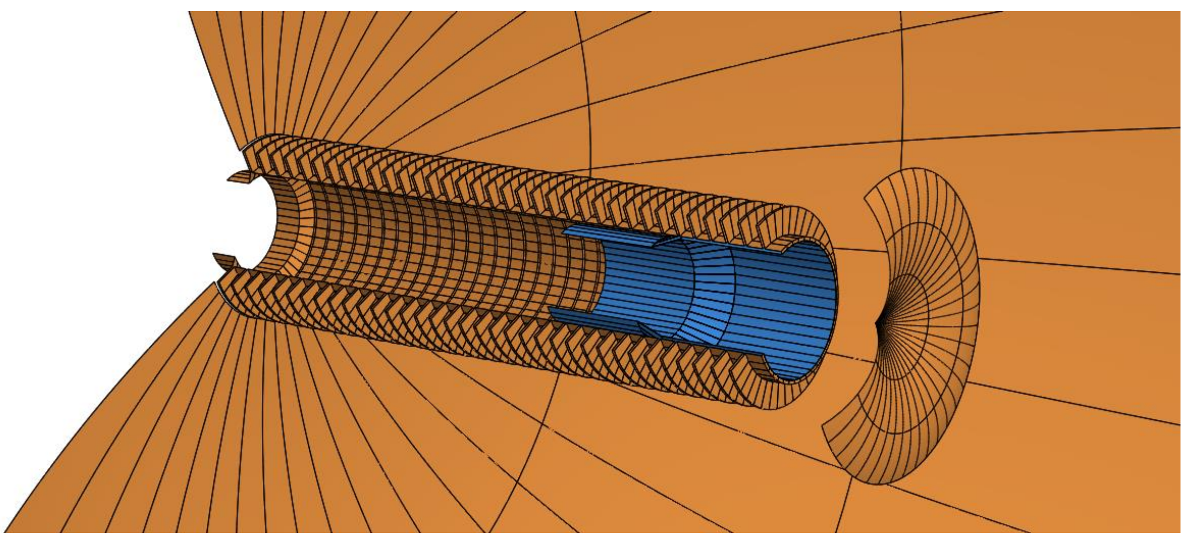

Figure 8-23.2a Turrin Feed Horn (blue) with 35 external corrugations along feed tube and initial un-shaped subreflector

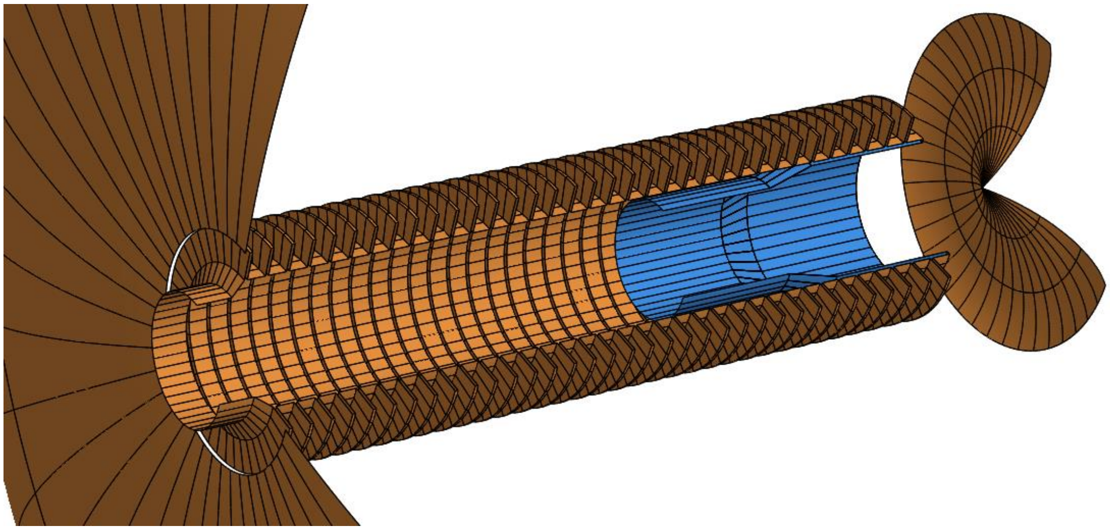

Figure 8-23.2b Turrin Feed Horn (blue) with 35 external corrugations along feed tube and initial un-shaped subreflector

The normal main reflector hole usually the diameter of the subreflector has been shrunk to be slightly greater than the outer diameter of the external corrugations. The main reflector geometry.tor addition uses 11 points in the spline of a "spline_circ_sym_reflector" CHAMP object.

```
z_focal_point   real_variable
(
  value    : 0.0
)

zmain1   real_variable
(
   value    : -1.824625E+02
)

zmain2   real_variable
(
   value    : -1.821806E+02
)

zmain3   real_variable
(
   value    : -1.788767E+02
)

zmain4   real_variable
(
   value    : -1.725506E+02
)

zmain5   real_variable
(
   value    : -1.632025E+02
)
```

```
zmain6   real_variable
(
   value    : -1.508323E+02
)

zmain7   real_variable
(
   value    : -1.354400E+02
)

zmain8   real_variable
(
   value    : -1.170256E+02
)

zmain9   real_variable
(
   value    : -9.558913E+01
)

zmain10   real_variable
(
   value    : -7.113058E+01
)

zmain11   real_variable
(
   value    : -4.364998E+01
)

ring_focus_main_reflector  spline_circ_sym_reflector
(
  z_offset         : "ref(z_focal_point)" mm,
  length_unit      : mm,
  nodes            : table
    (
     2.710000E+01   "ref(zmain1)"
     6.189000E+01   "ref(zmain2)"
     9.668000E+01   "ref(zmain3)"
     1.314700E+02   "ref(zmain4)"
     1.662600E+02   "ref(zmain5)"
     2.010500E+02   "ref(zmain6)"
     2.358400E+02   "ref(zmain7)"
     2.706300E+02   "ref(zmain8)"
     3.054200E+02   "ref(zmain9)"
     3.402100E+02   "ref(zmain10)"
     3.750000E+02   "ref(zmain11)"
    )
)
```

The subreflector spline addition is similar.

```
z_focal_point   real_variable
(
  value    : 0.0
)
```

```
zsub1   real_variable
(
   value    :  2.510002E+01
)

zsub2   real_variable
(
   value    :  2.842220E+01
)

zsub3   real_variable
(
   value    :  3.093849E+01
)

zsub4   real_variable
(
   value    :  3.281464E+01
)

zsub5   real_variable
(
   value    :  3.413161E+01
)

zsub6   real_variable
(
   value    :  3.492361E+01
)

zsub7   real_variable
(
   value    :  3.519065E+01
)

zsub8   real_variable
(
   value    :  3.489849E+01
)

zsub9   real_variable
(
   value    :  3.396621E+01
)

zsub10   real_variable
(
   value    :  3.222804E+01
)

ring_focus_sub_reflector  spline_circ_sym_reflector
(
  z_offset         : "ref(z_focal_point)" mm,
  length_unit      : mm,
  nodes            : table
```

```
    (
     0.000000E+00    "ref(zsub1)"
     4.583333E+00    "ref(zsub2)"
     9.166667E+00    "ref(zsub3)"
     1.375000E+01    "ref(zsub4)"
     1.833333E+01    "ref(zsub5)"
     2.291667E+01    "ref(zsub6)"
     2.750000E+01    "ref(zsub7)"
     3.208334E+01    "ref(zsub8)"
     3.666667E+01    "ref(zsub9)"
     4.125000E+01    "ref(zsub10)"
    )
)
```

Each spline reflector addition contains the variable: "z_focal_point" which shifts the reflectors to the phase center of the feed. Only one of these is needed. The phase center is located 1.3 mm inside the Turrin horn.

```
z_focal_point  real_variable
(
  value             : -1.3
)
```

These two reflectors are added to the scatterers list at the top of the geometry.tor file.

```
  scatterers        :
sequence(ref(horn_exterior),ref(ring_focus_sub_reflector),ref(ring_focus_main_reflector))
)
```

After adding these additions to the CHAMP geometry.tor, CHAMP generates the geometry shown in Figures 8-23.1 and 8-23.2.

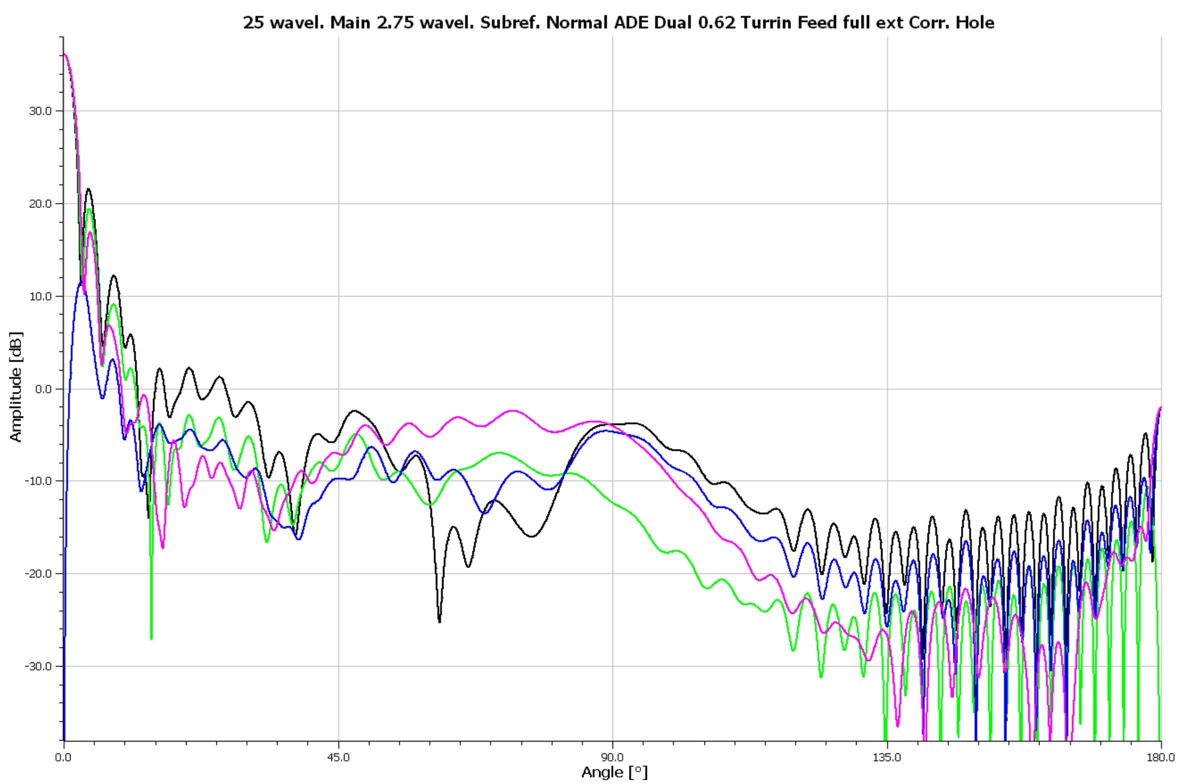

Figure 8-23.4 Pattern of normal displaced axis dual reflector with decreased central hole of main reflector

The pattern of Figure 8-23.4 has a directivity of 36.32 dB. The front lobe pattern is as follows.

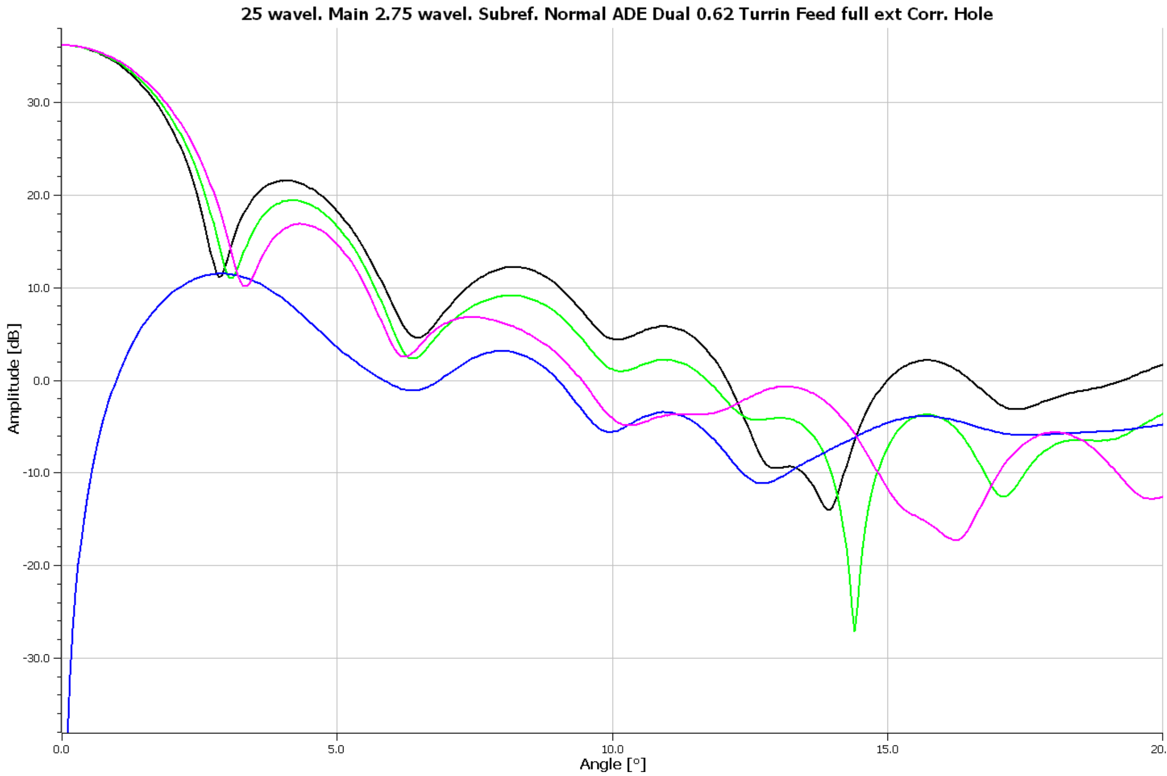

Figure 8-23.5 Front lobe Pattern of normal displaced axis dual reflector with decreased central hole of main reflector

If we reduce the external corrugations to only 8, the back lobe increases.

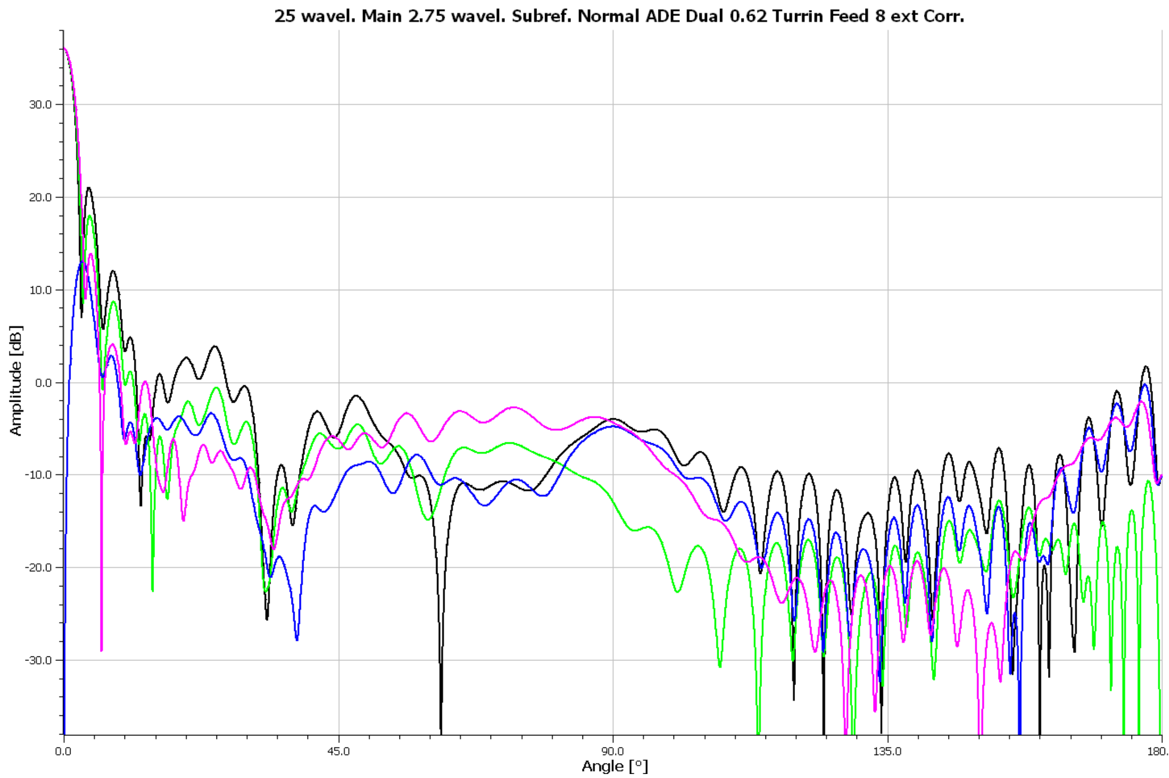

Figure 8-23.5 Pattern of normal displaced axis dual reflector with normal central hole of main reflector and only 8 corrugations along feed tube

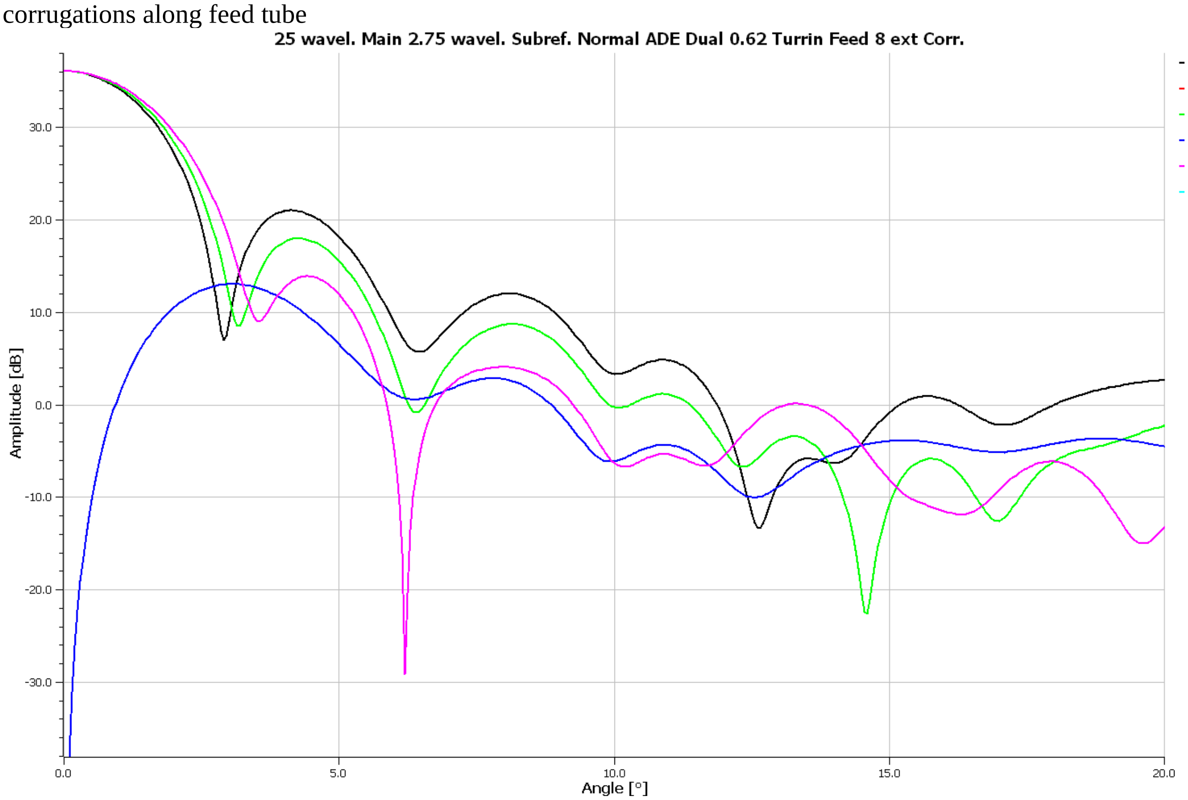

Figure 8-23.6 Front lobe Pattern of normal displaced axis dual reflector with normal central hole of main reflector and only 8 corrugations along feed tube

With only 8 feed tube external corrugations and the normal displaced axis main reflector hole directivity drops to 36.07 dB. We will compare this to using normal Cassegrain and Gregorian dual reflectors for a Turrin horn with 8 external corrugations. The program GRANETDS generates the spline additions to the geometry.tor file both the Cassegrain and Gregorian dual reflectors. The main reflector file is gram5.txt is the main reflector of the Cassegrain and gram6.txt for the Gregorian. The corresponding files are gras5.txt and gras6.txt. We use to modify the geometry.tor file for a Cassegrain or Gregorian CHAMP BOR-MoM analysis.

The Cassegrain with a subreflector diameter of 2.75λ has significant diffraction loss (Section 8-13.2) but a small central blockage. Directivity drops to 34.7 dB, see Figures 8-23.7 and 8-23.8. The curved small subreflector of the Gregorian reflector has less diffraction loss and directivity 36.18 stays comparable to the displaced axis reflector. Figures 8-23.9 and 8-23.10 plot the Gregorian analysis.

We use the optimizer in CHAMP with three goals: maximum bore sight directivity, maximum return loss, and minimum sidelobes to the template, a) 29 - 25log θ dBi for $1.5^\circ \le \theta \le 7^\circ$, b) 8 dBi for $7^\circ \le \theta \le 9.2^\circ$, c) 32 - 25 log θ for $9.2^\circ \le \theta \le 48.2^\circ$, d) -10 dBi $48^\circ \le \theta \le 180^\circ$. The first three corrugation heights and their spacings plus the splines values of the main and subreflector are used as optimization variables. Shaping the reflectors to minimize sidelobes reduces directivity because a uniform phase in the aperture plane is sacrificed. Optimization greatly alters the subreflector geometry while changes to the main reflector are small, see Figures 8-23.11, 8-23.12, and 8-23.12. The first few corrugations have been changed to improve F/B and return loss.

Figure 8-23.14 shows the CHAMP BOR-MoM model of the feed horn, optimized subreflector without the main reflector. The diffraction pattern of feed plus un shaped subreflector is plotted in Figure 8-23.15. Its pattern at 180° points to the main reflector. The combination of the optimized subreflector and corrugated feed tube plus feed horn, Figure 8-23.16 shows the reduced bore sight pattern and clustering of pattern in the direction of the main reflector. Remember this is only a 2.75λ diameter splash plate which limits its ability to control the pattern.

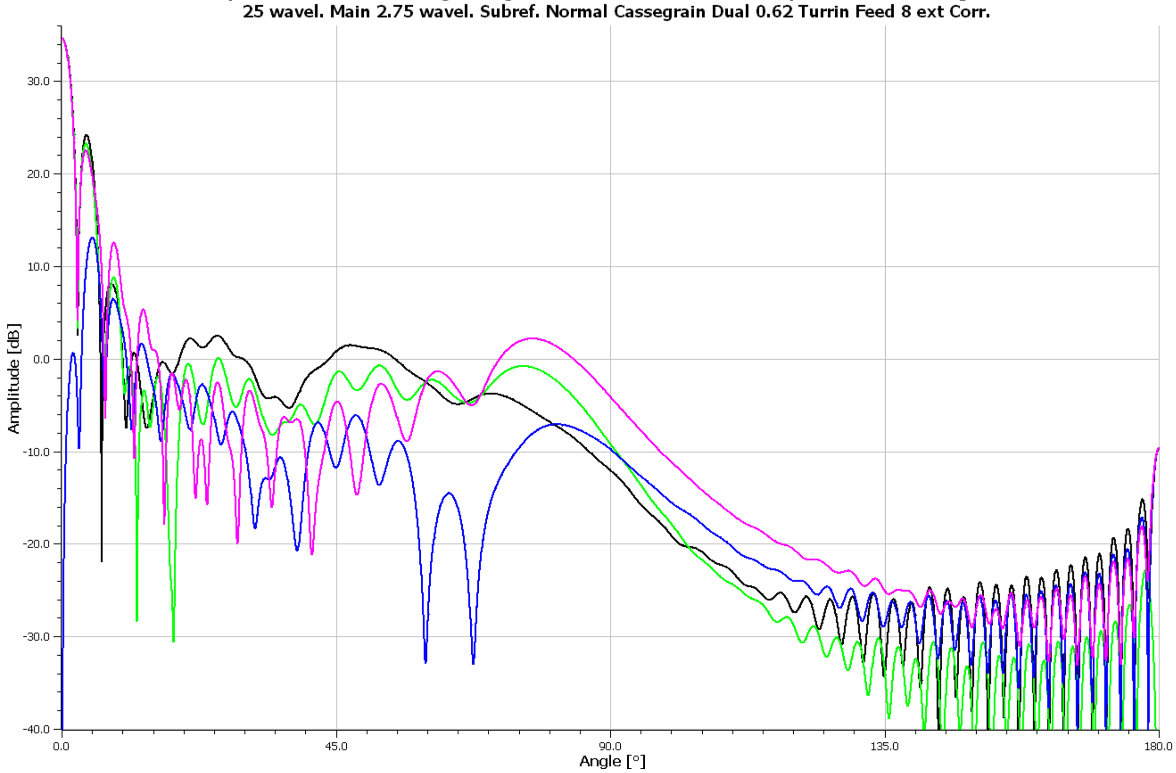

Figure 8-23.7 Pattern of Cassegrain dual reflector with complete main reflector and only 8 corrugations along feed tube of Turrin feed horn

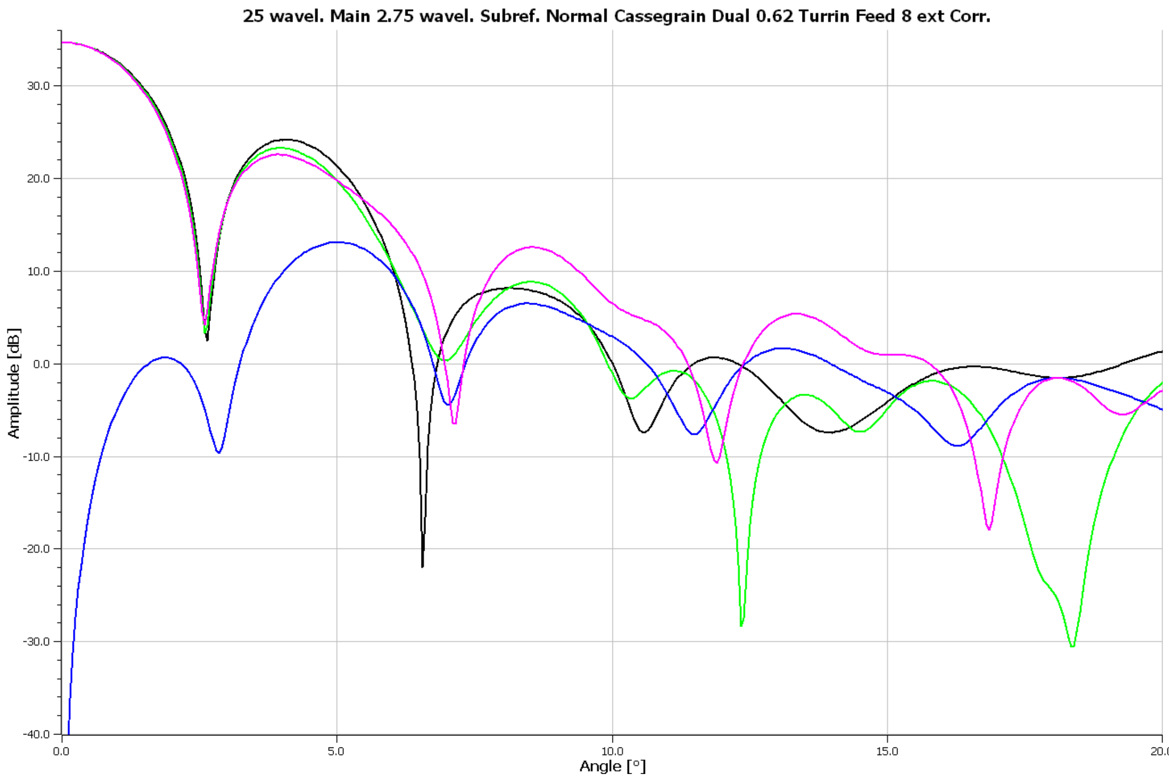

Figure 8-23.8 Front Lobe Pattern of Cassegrain dual reflector with complete main reflector and only 8 corrugations along feed tube of Turrin feed horn

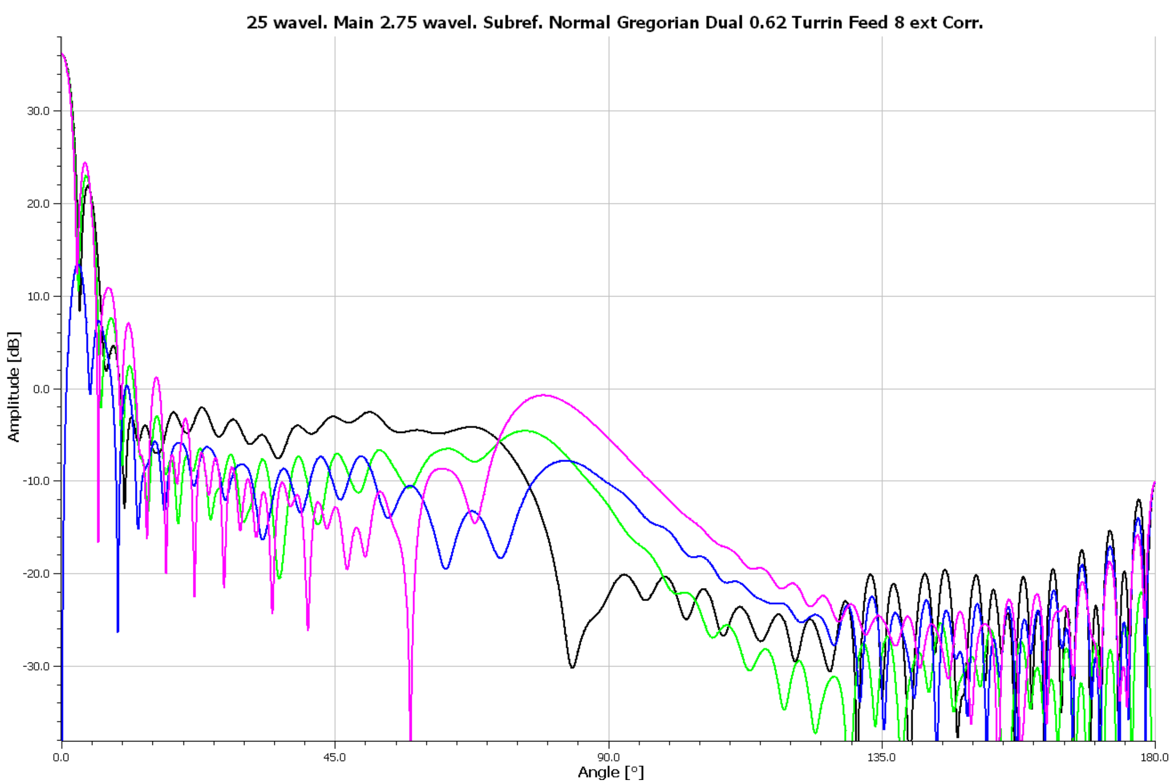

Figure 8-23.9 Pattern of Gregorian dual reflector with complete main reflector and only 8 corrugations along feed tube of Turrin feed horn

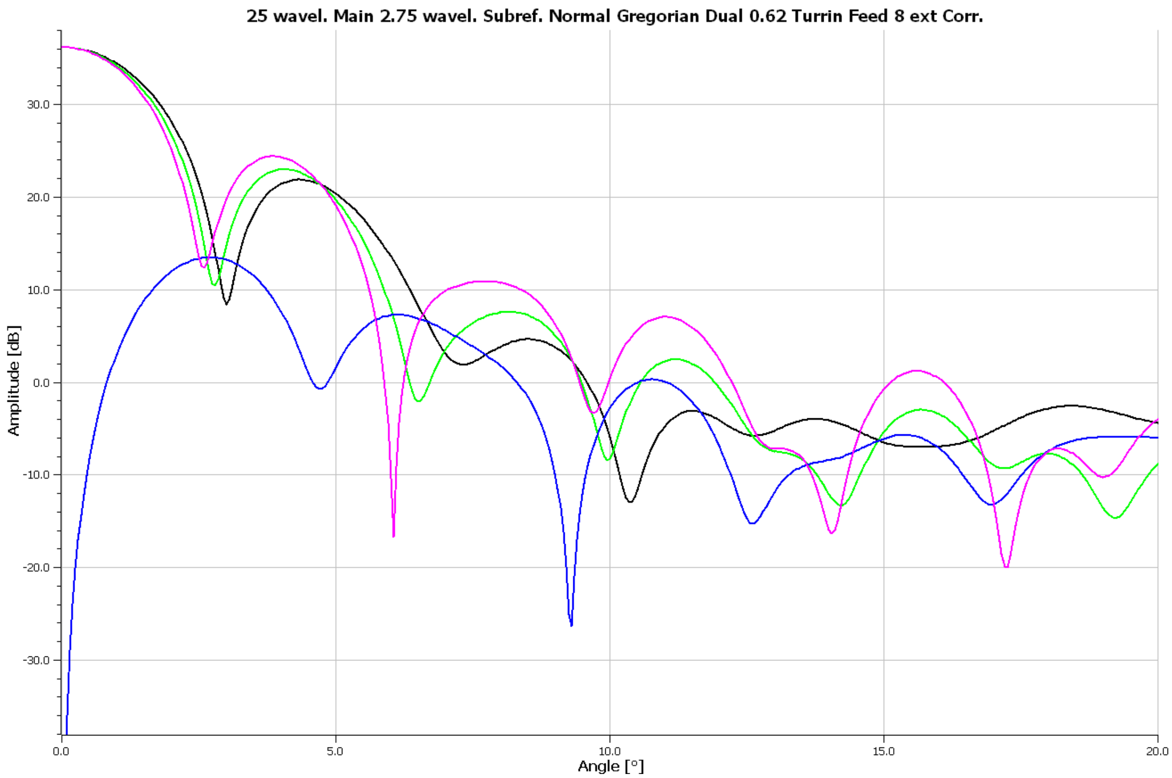

Figure 8-23.10 Front Lobe Pattern of Gregorian dual reflector with complete main reflector and only 8 corrugations along feed tube of Turrin feed horn

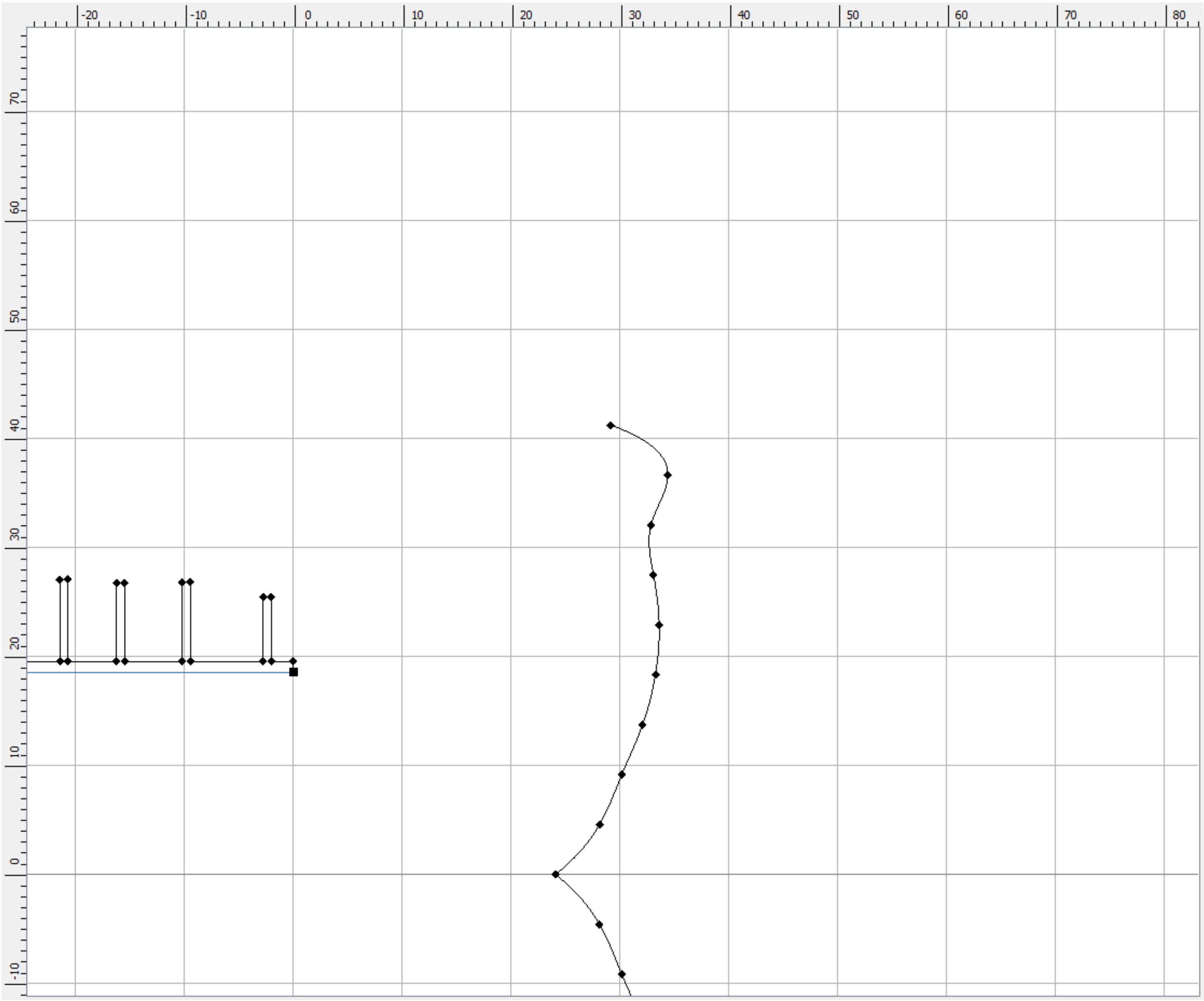

Figure 8-23.11 Optimum subreflector and first few corrugations

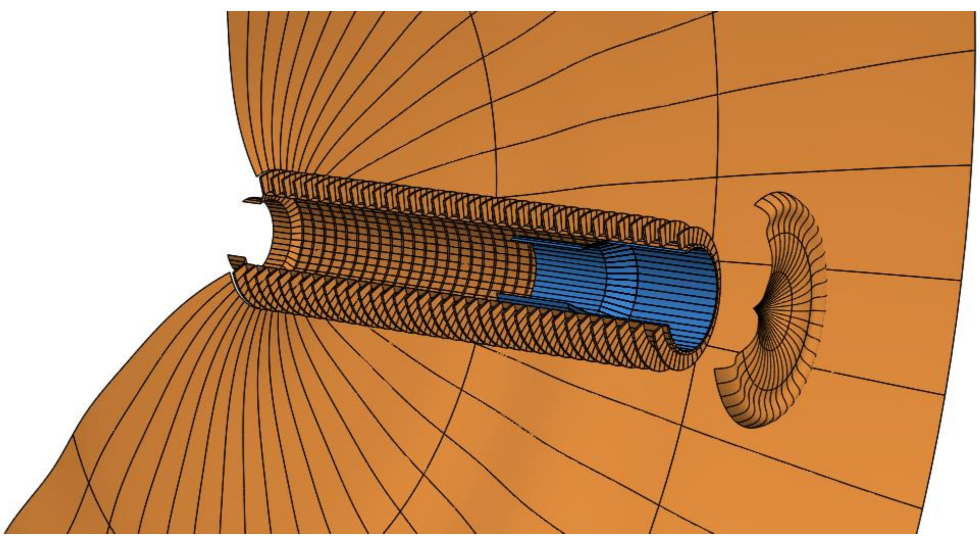

Figure 8-23.12 Optimum subreflector and corrugations

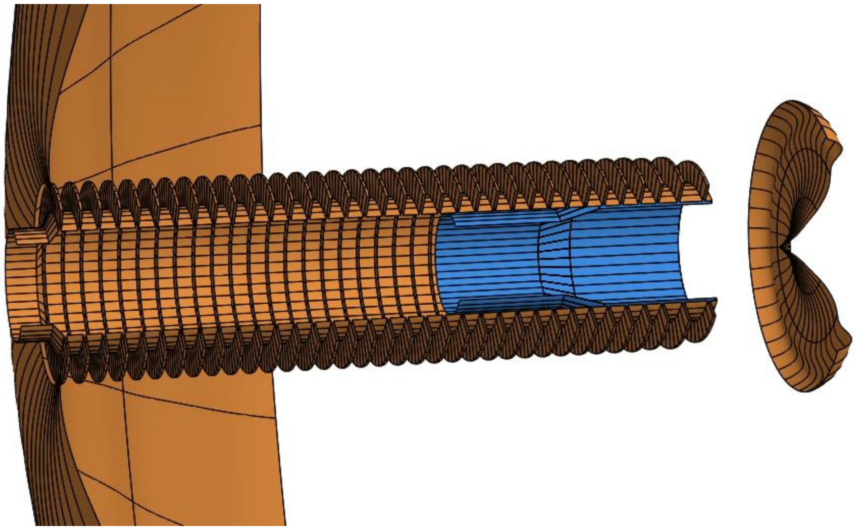

Figure 8-23.13 Optimum subreflector and corrugations

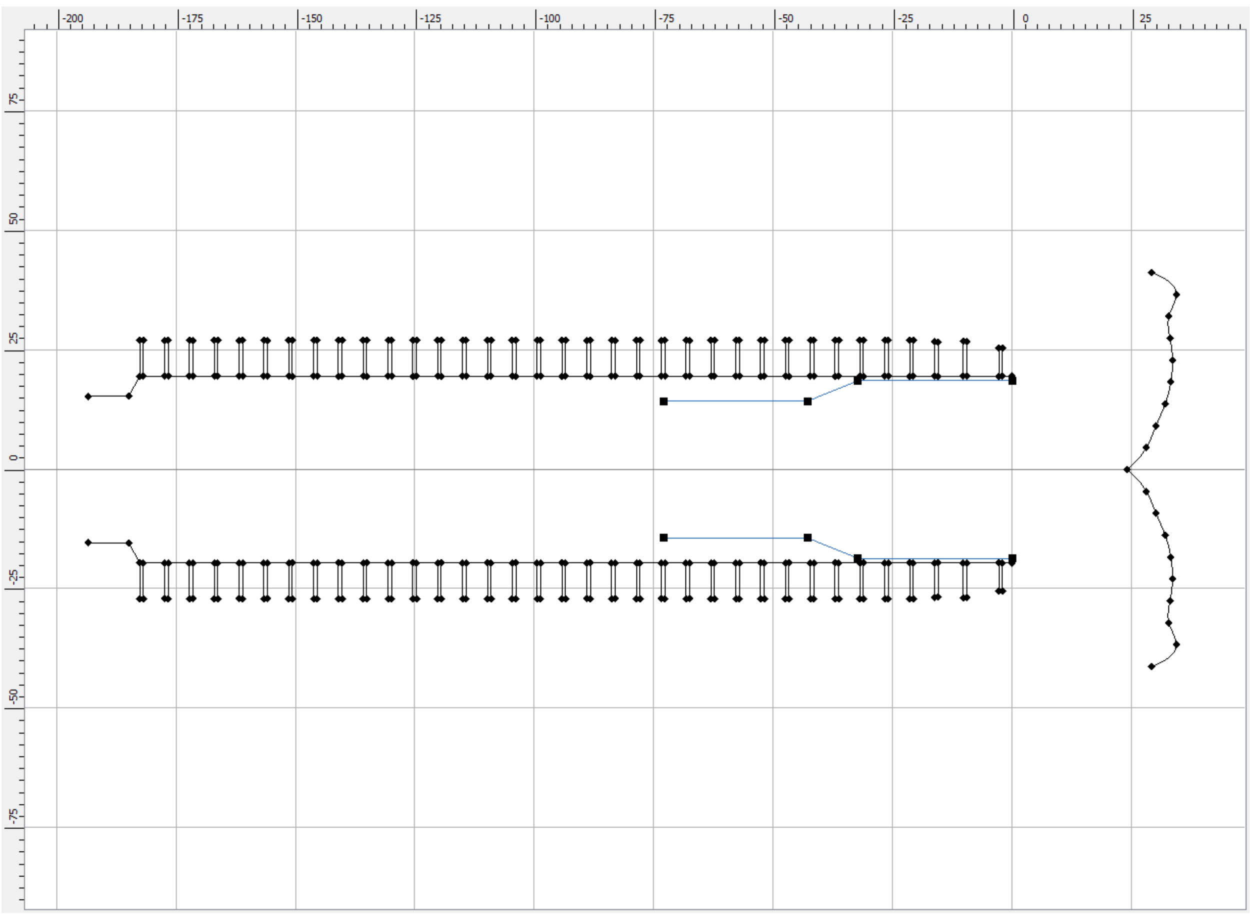

Figure 8-23.14 Model of optimized Subreflector and Turrin Horn Feed with full External Corrugated Feed Tube

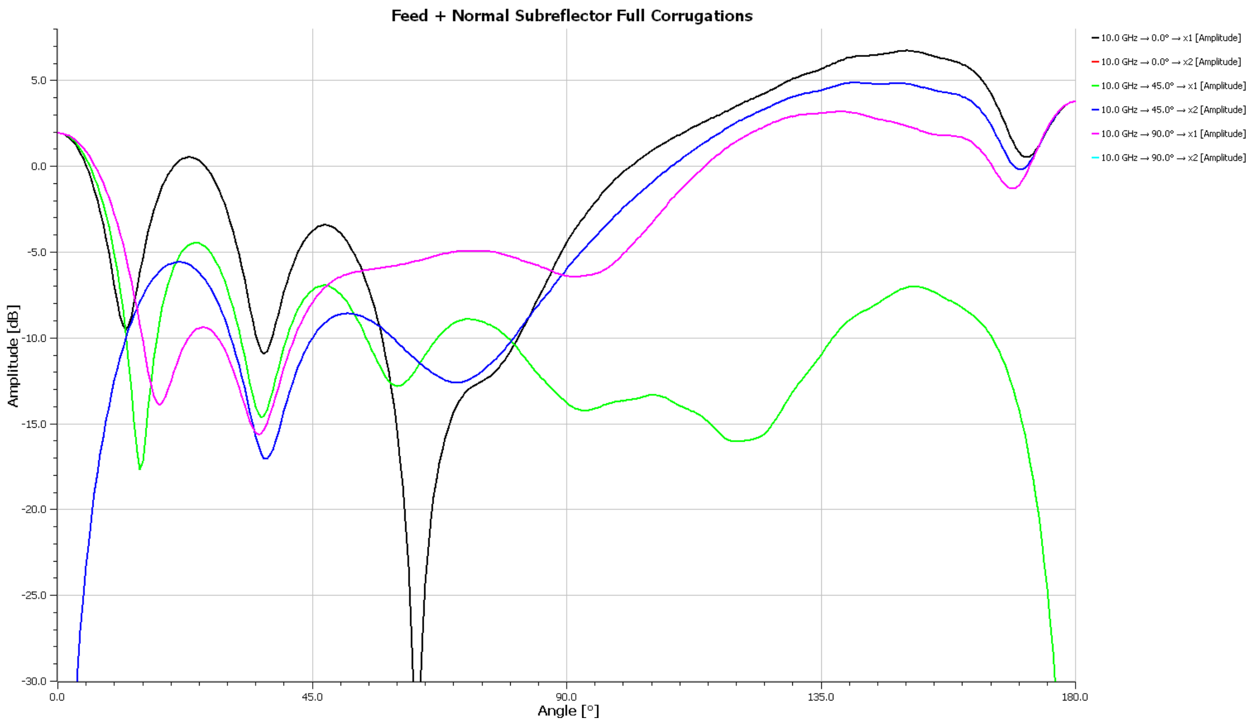

Figure 8-23.15 Feed Horn and scattered Pattern of a normal un-shaped subreflector, and corrugated feed tube of the displaced axis reflector

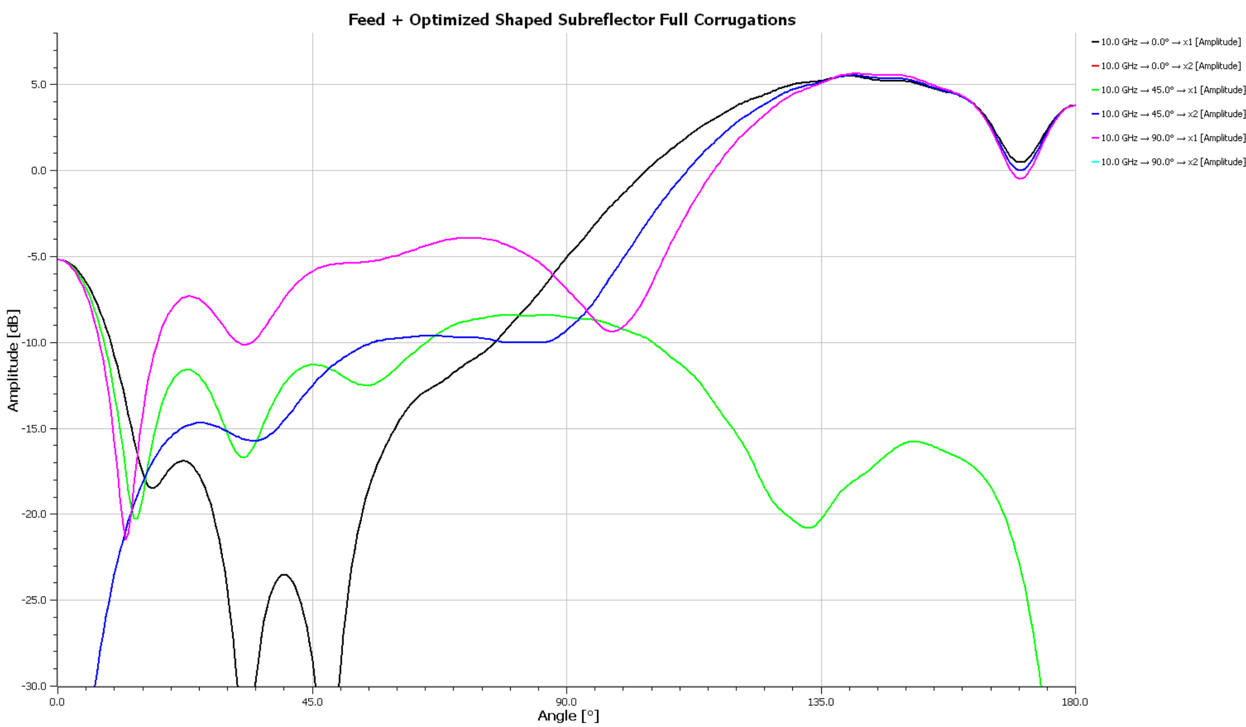

Figure 8-23.16 Feed Horn and scattered Pattern of a shaped subreflector, and corrugated feed tube of the displaced axis reflector

Dielectric Support Cone for Subreflector

Figure 8-23.17 shows the geometry of a dielectric support cone where the subreflector is supported off the Turrin feed horn with its external corrugations. We groove the end that attaches to the cone so that it will slip on the horn outside and meets the inner radius without a step. The exterior of the horn must be a cylinder and not a cone. Larger gain feed horns need a short cylindrical length instead of a cone. Of course, the distance to the first exterior corrugation has to be greater than the dielectric connection. It can be constrained to a minimum in the optimization.

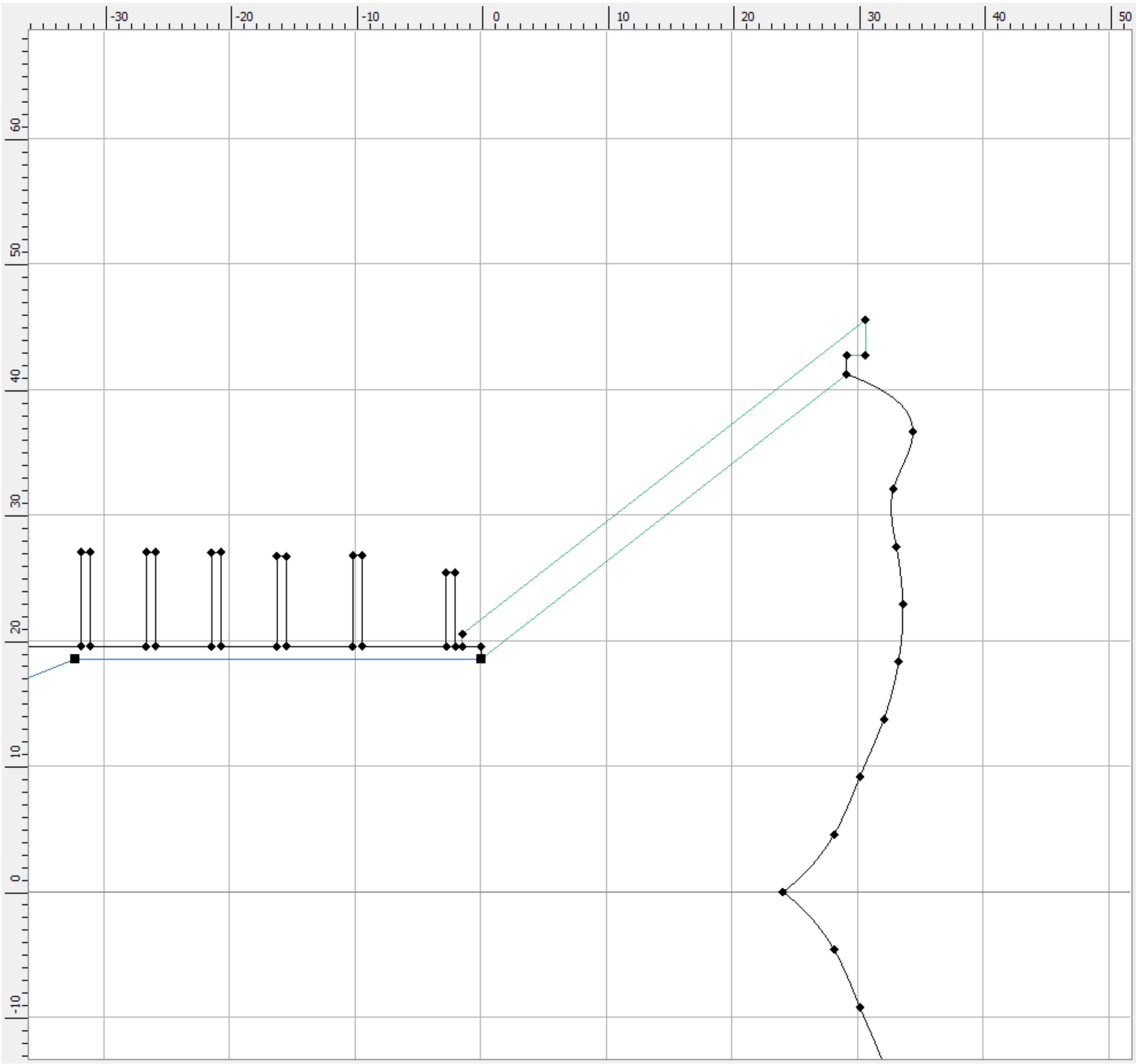

Figure 8-23.17 Champ geometry of Dielectric Support Cone

The lower end of the dielectric support cone meets the last point of the optimized spline of the subreflector. In this case the subreflector has been extended a short vertical distance. The subreflector slips into the dielectric cone and is attached along this small extension. The dielectric support cone alters the pattern response of the dual reflector and the cone needs to adjusted inside the optimization. We specify the subreflector end of the dielectric cone with the variable of subreflector spline. The program CHSCONE generates the geometry.tor addition for this dielectric cone.

When we add the output from CHSCONE, we must make a few changes to the geometry.tor besides just adding its variables and "BOR_MESH" section. The dielectric cone includes the metal vertical end of feed horn and the length along the outside. These are removed from the "HORN_EXTERIOR" by changing "snap_to_aperture" to off.

```
horn_exterior  circular_symmetric_horn_exterior
(
  snap_to_aperture : off,
  length_unit      : mm,
```

The initial *z*-axis position is changed to the contact length of the dielectric cone along the exterior.

```
ZW1  real_variable
(
  value            : 1.5
)
```

The dielectric support is added to the scatterers list near the top of the geometry.tor file.

```
  scatterers       :
sequence(ref(horn_exterior),ref(ring_focus_sub_reflector),ref(ring_focus_main_reflect
or),ref(support_cone))
)
```

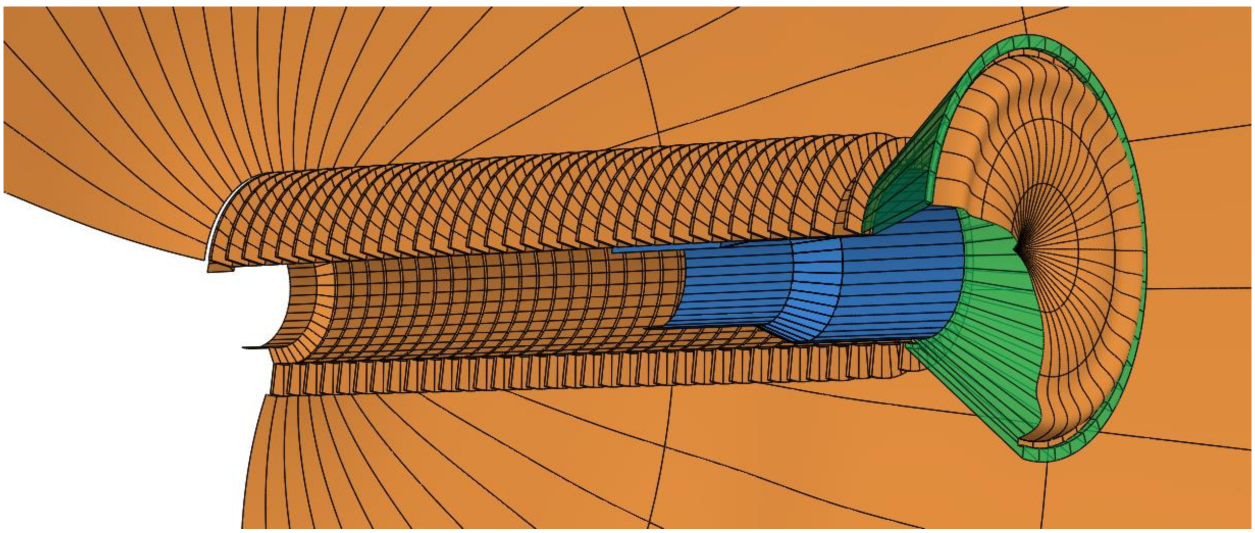

Figure 8-23.18 Central Feed Tube with Dielectric Support Cone

The support cone changes the pattern and return loss responses from the initial optimization. We run another optimization which includes this new structure. The BOR_MESH object includes the optimization of the last *z*-axis variable of the subreflector and adjusts the exterior by using unit vectors and thickness to find the dielectric cone exterior points as the length and angle of the cone changes in the optimization.

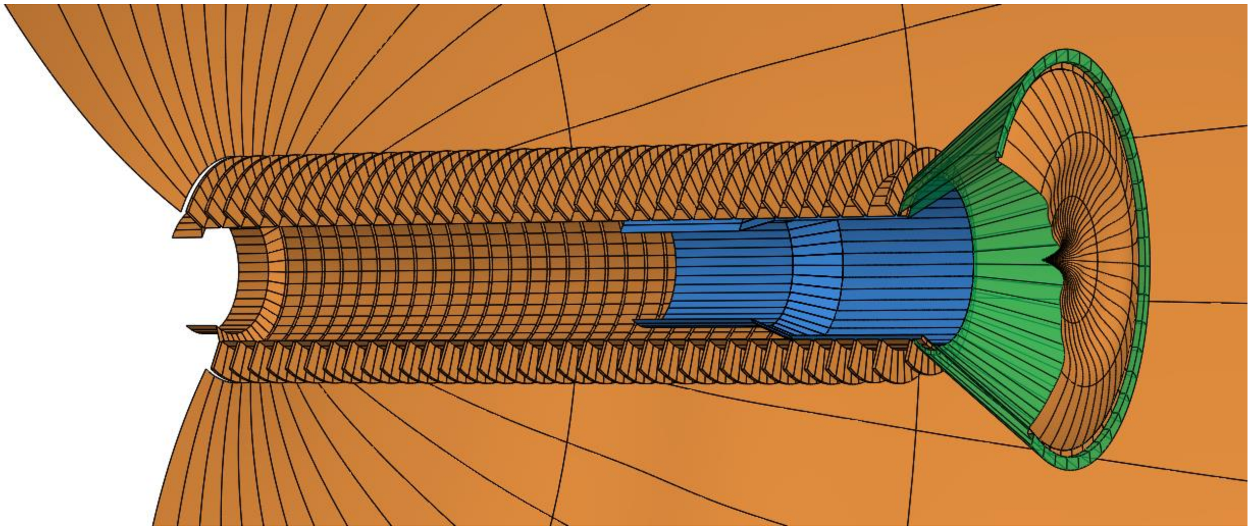

Figure 8-23.19 Optimized Central Feed Tube with Dielectric Support Cone

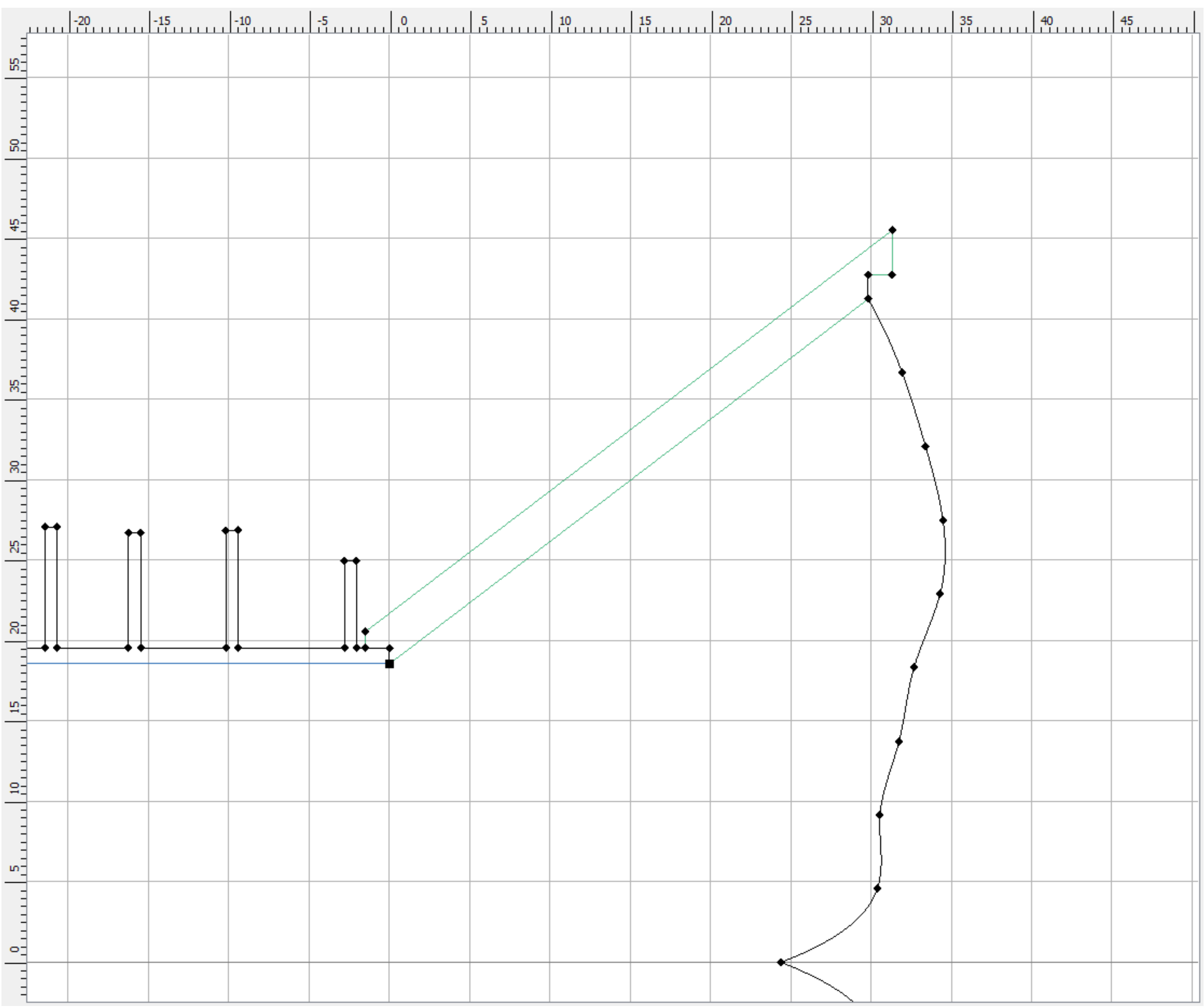

Figure 8-23.20 Optimized Champ geometry of Dielectric Support Cone

A comparison between Figures 8-23.17 and 8-23.20 shows a lengthening of the cone with a smaller cone angle.

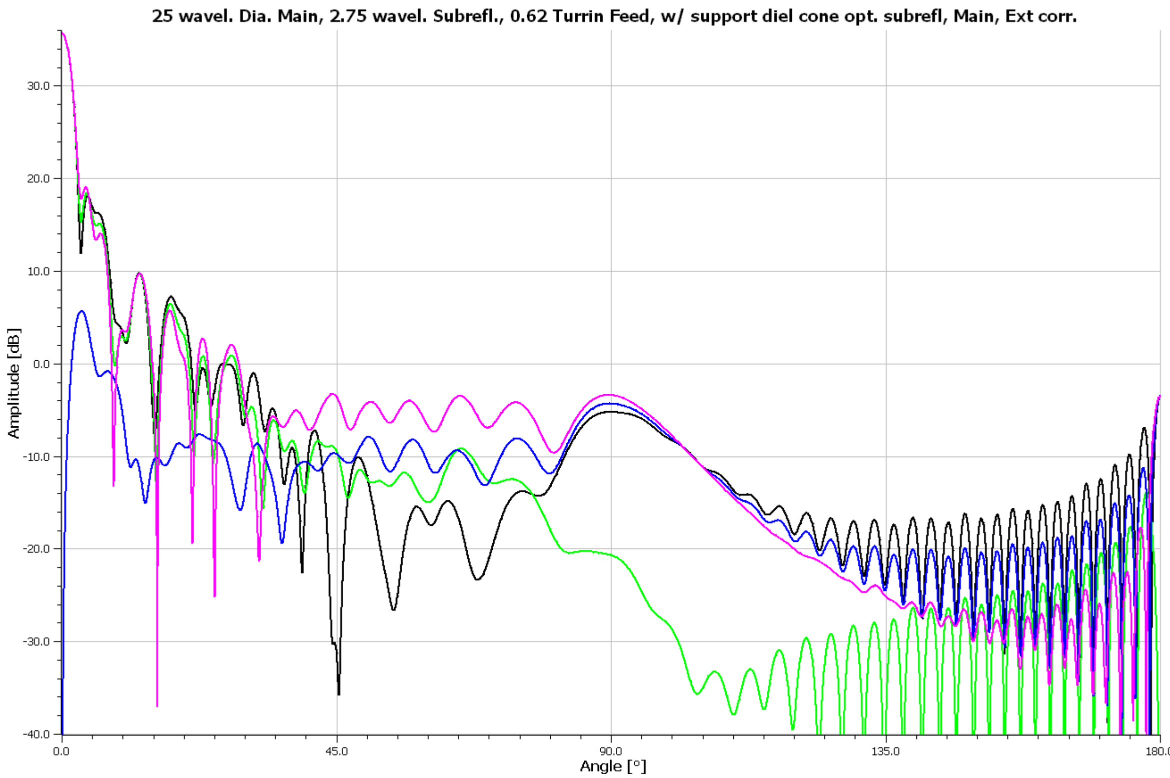

Figure 8-23.21 Optimized Reflector with dielectric support cone of Optimized subreflector and main reflector using 0.62λ diameter Turrin horn with full length exterior corrugations

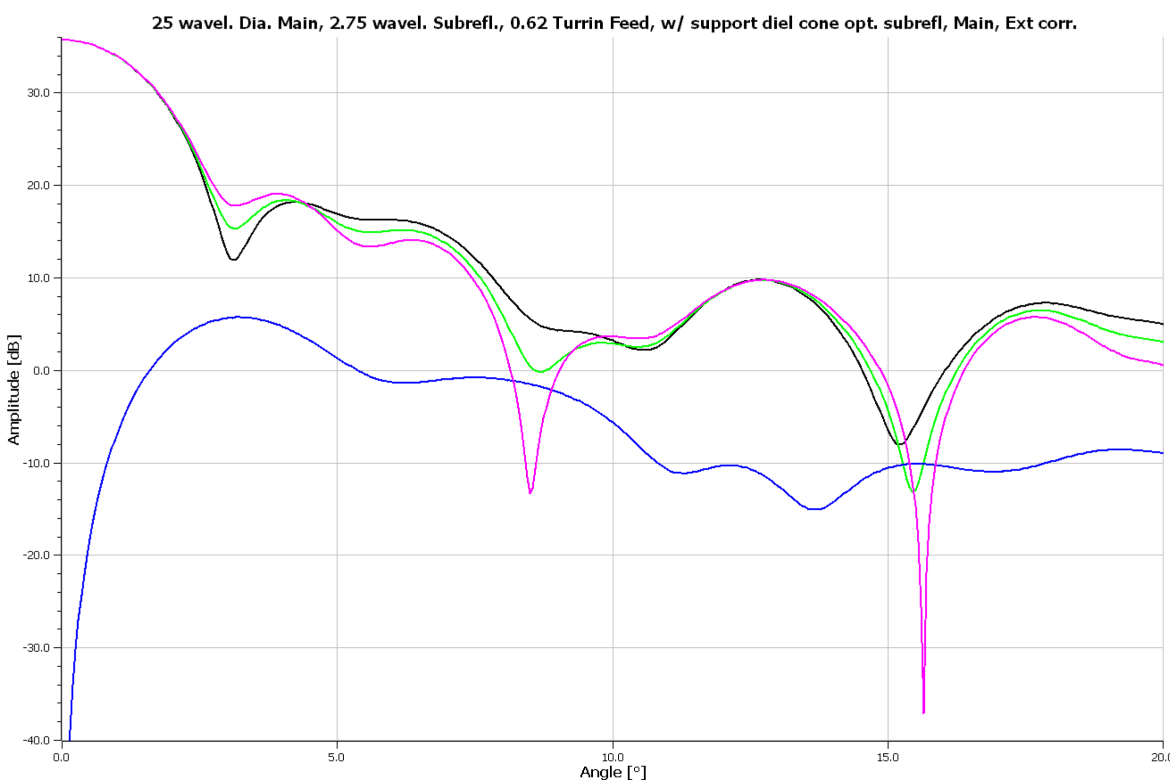

Figure 8-23.22 Front lobe of Optimized Reflector with dielectric support cone of Optimized subreflector and main reflector using 0.62λ diameter Turrin horn with full length exterior corrugations

Optimized Sinusoidal Exterior Corrugations for Splash Plate Reflector

Section 7-3.5 illustrated the use of sinusoidal exterior corrugations to control the backlobe of horn. These corrugations can be used as variables in the optimization of the splash plate reflector. The program COWSPLI creates a CHAMP geometry.tor file addition for an initially sinusoidal exterior corrugated section using sufficient points along the curve to approximate a spline curve for optimization.

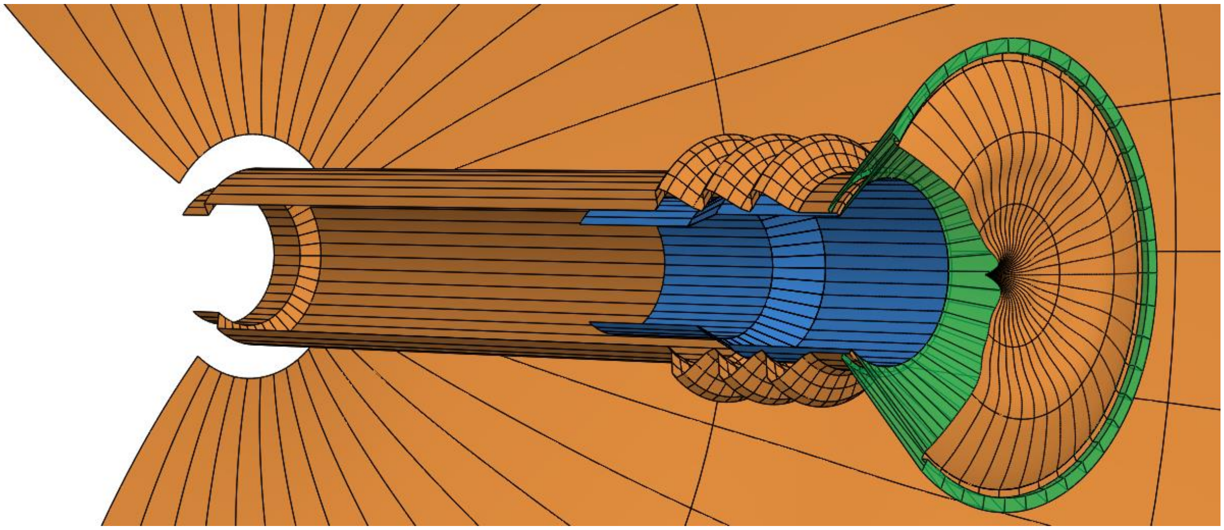

Figure 8-23.23 Turrin Horn Feed with exterior Sinusoidal Corrugations exciting Shaped Splash Plate supported by a Dielectric Cone

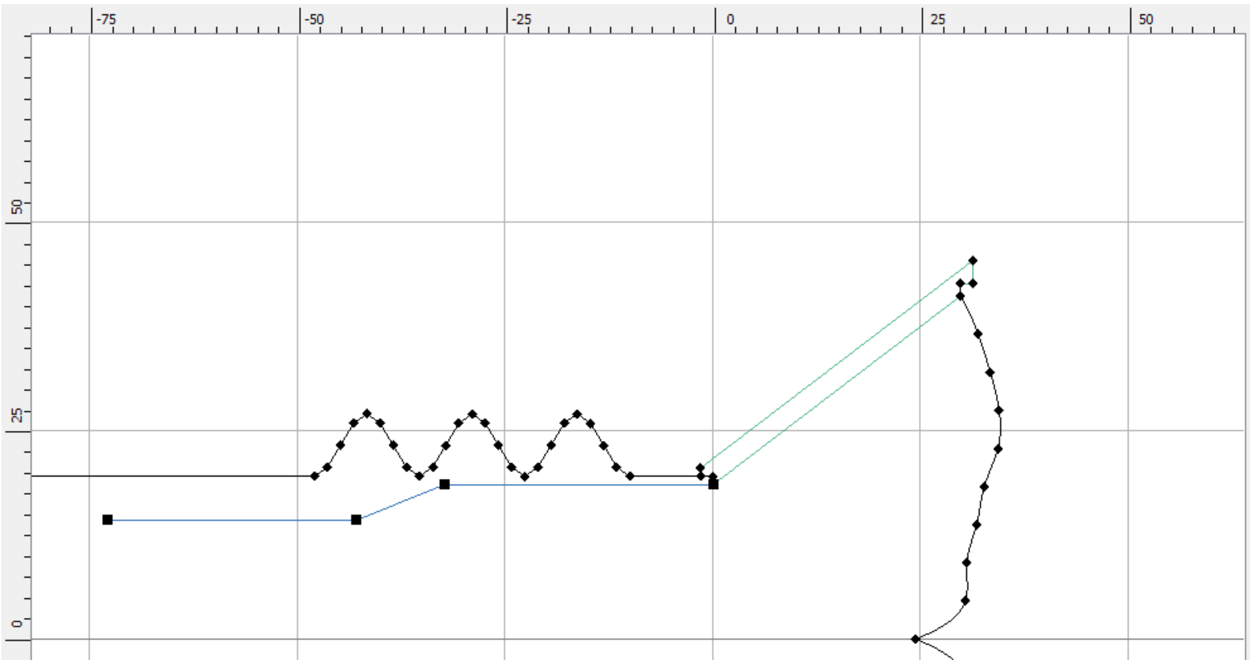

Figure 8-23.24 CHAMP geometry of Turrin Horn Feed with exterior Sinusoidal Corrugations exciting Shaped Splash Plate supported by a Dielectric Cone

Because the dielectric cone includes the metal horn end and metal along the exterior, ZW1 must be modified to match the dielectric length along the exterior. "Snap_to_aperture" of the horn_exterior must be set to off .
The un-optimized sinusoidal corrugations combined with the optimized splash plate contour and main reflector produce good patterns.

The initially sinusoidal corrugated section was optimized using the radial lengths and position to the horn aperture as variables. Change in the start of corrugations is matched with the final tube length to keep their sum constant.

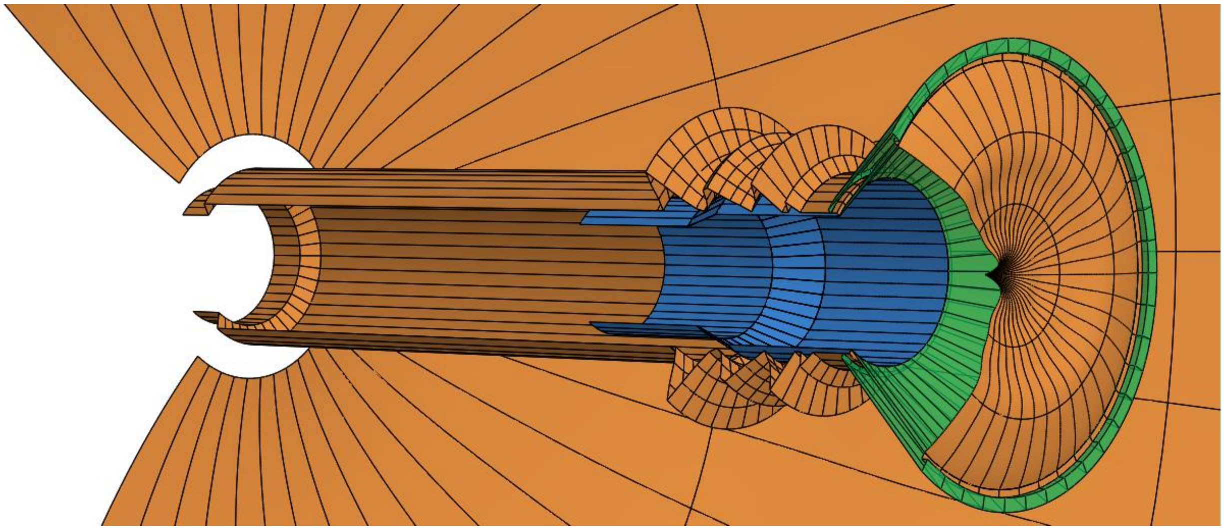

Figure 8-23.25 Turrin Horn Feed with exterior optimized shaped feed tube exciting Shaped Splash Plate supported by a Dielectric Cone

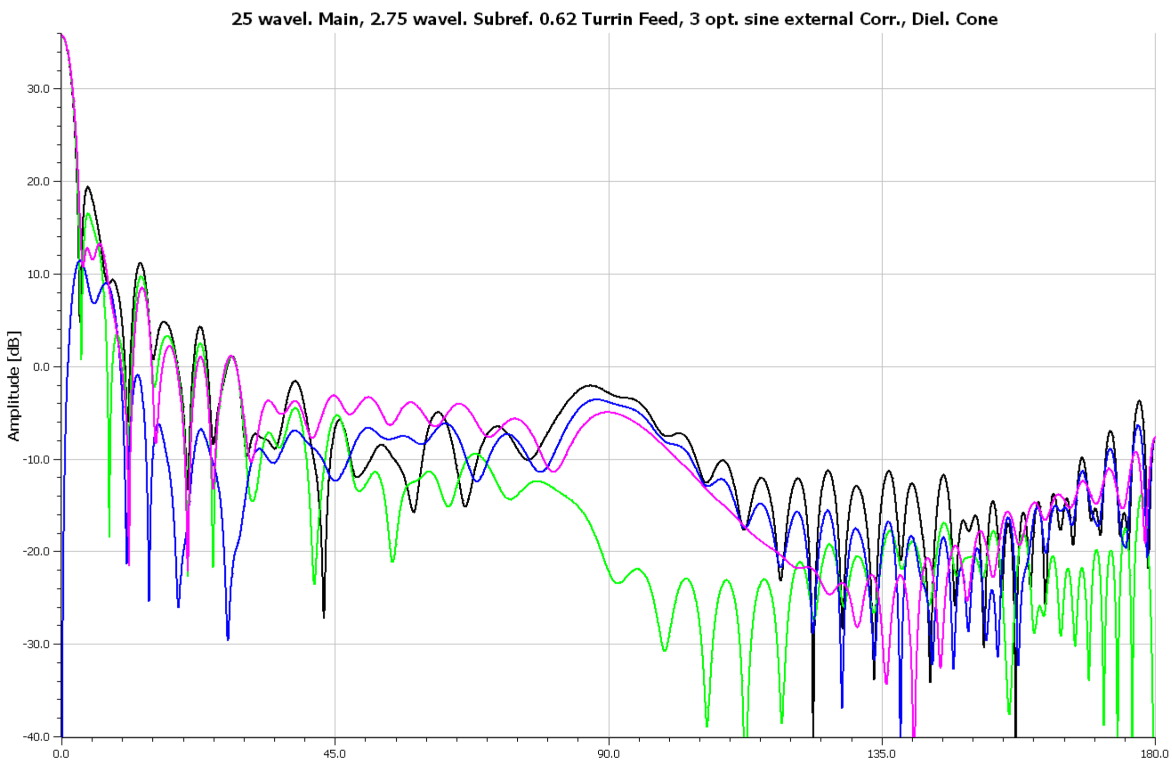

Figure 8-23.26 Optimized Reflector with dielectric support cone of Optimized splash plate and main reflector using 0.62λ diameter Turrin horn with optimized short length spline shaped feed tube exterior

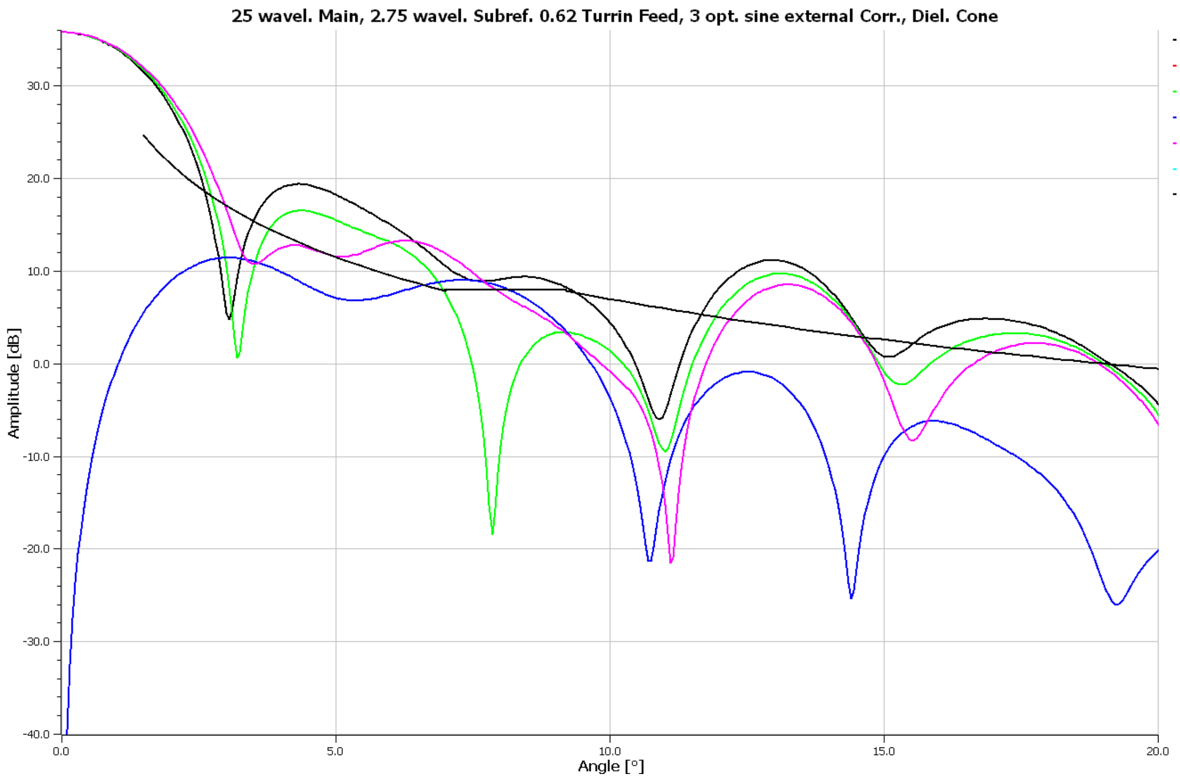

Figure 8-23.27 Front lobe of Optimized Reflector with dielectric support cone of Optimized splash plate and main reflector using 0.62λ diameter Turrin horn with optimized short length spline shaped feed tube exterior