GEM-P Progress Report
Optics
(July 2006)

1. Receiver

The GEM-Portugal project uses a digital correlation receiver, with operating central frequency at 4.9GHz and a bandwidth of 200 MHz. The receiver will provide as output, I, Q and U Stokes parameters, simultaneously. A thorough description will be given in another dedicated report.

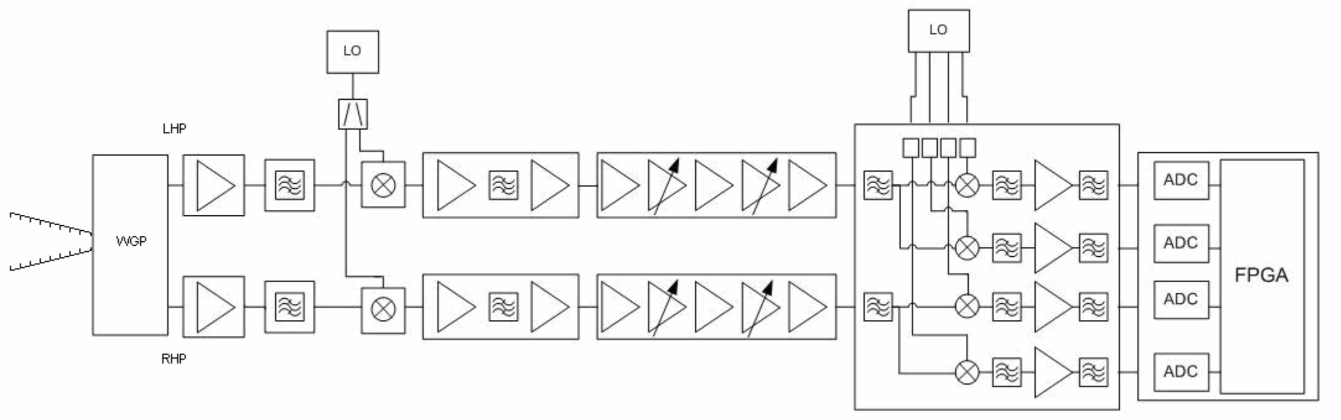

Fig. 1 - Receiver design

1.1.1. Sensitivity and integration, Tsys

The synchrotron signal to be measured will be very dim, an expected 1 mK. This signal will be immerse in the overall signal entering the receiver, known as system noise temperature and it have values around 20 k for our system. The system noise temperature is decomposed in three components, sky temperature, antenna temperature and receiver temperature.

To obtain the maximum signal over noise ratio, we need to minimize as much as possible the system temperature. Antenna temperature resulting from ground spillover will be decreased by using a ground shield that will block the ground and redirect to the sky, which is at a lower temperature. Receiver temperature decrease is accomplished by using front end components with the lower possible noise figures. Cooling down to cryogenic values the first stage amplifiers and building a horn with silver coating will give a valuable contribution in that pursuit.

$$T_{sys} = T_{sky} + T_{ant} + T_{rec}$$

Receiver Noise Temperature (July 2006)		
T_{sky}	Sky noise temperature	4.9 K
T_{ant}	Antenna noise temperature	~ 3.7 K
T_{rec}	Receiver noise temperature	13.9 K
T_{sys}	System noise temperature	22.48 K

To be able to detect the synchrotron signal buried in noise, integration of many samples is needed to achieve the required sensitivity.
Receiver sensitivity is given by,

$$\Delta T = k\, T_{sys} \sqrt{\frac{1}{B\tau}}$$

, where B is the bandwidth, τ is the sample or integration time, k is a constant dependent of receiver design and T_{sys} the system noise temperature. For $k=2^{½}$ and $\tau=0.084$ seconds for each pixel, sensitivity will be 7.8 mK. To achieve 1 mk sensitivity and considering 1 sample per day per pixel, the total needed observing period will be 61 days.

2. Antenna

2.1. General Configuration

The antenna to be used is a 9 meter Cassegrain focus configuration, C band, from Vertex RSI.
The original design was intended for telecommunications use, which are far from satisfying radio-astronomy antenna requisites. Additionally, one of the requirements is the protection of the receiver inside the antenna hub, which implies the need to design a new horn and a new subreflector. The subreflector will be supported by a quadripod strut configuration and the mount will be an elevation over azimuth arrangement.The new optical configuration is studied making use of the following software, GRASP-SE (TICRA), RASCAL (USC) and Plank available routines.

2.2. Horn

The horn is being designed with the collaboration of Dietmar Wagner, from the Max Planck Institute for Plasma Physics and using HFSS (ANSOFT) software.

2.2.1. Specifications and Requirements

- Frequency receiving band: 200 MHz centered at 5 GHz
- Polarization: circular
- Cross-polarization < -30 dB
- Ellipticity: < 0.75 dB
- Insertion loss: < 0.05dB (silver coated)
- Target illumination function: starting analysis with -12 dB at 14º from main-beam direction
- Side lobe level: < -30 dB
- Length and diameter: compact in length and diameter

2.2.2. First Design and HFSS Simulations

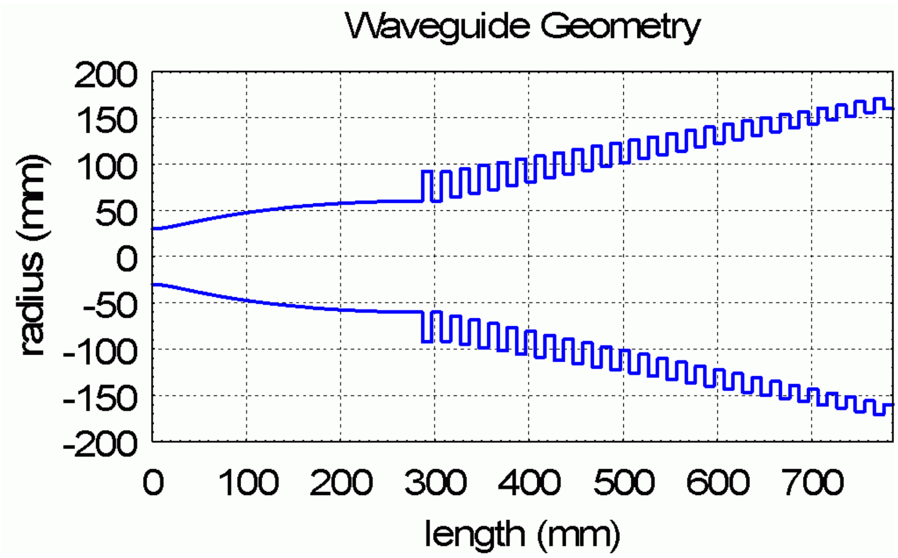

Fig. 2 - First horn geometry

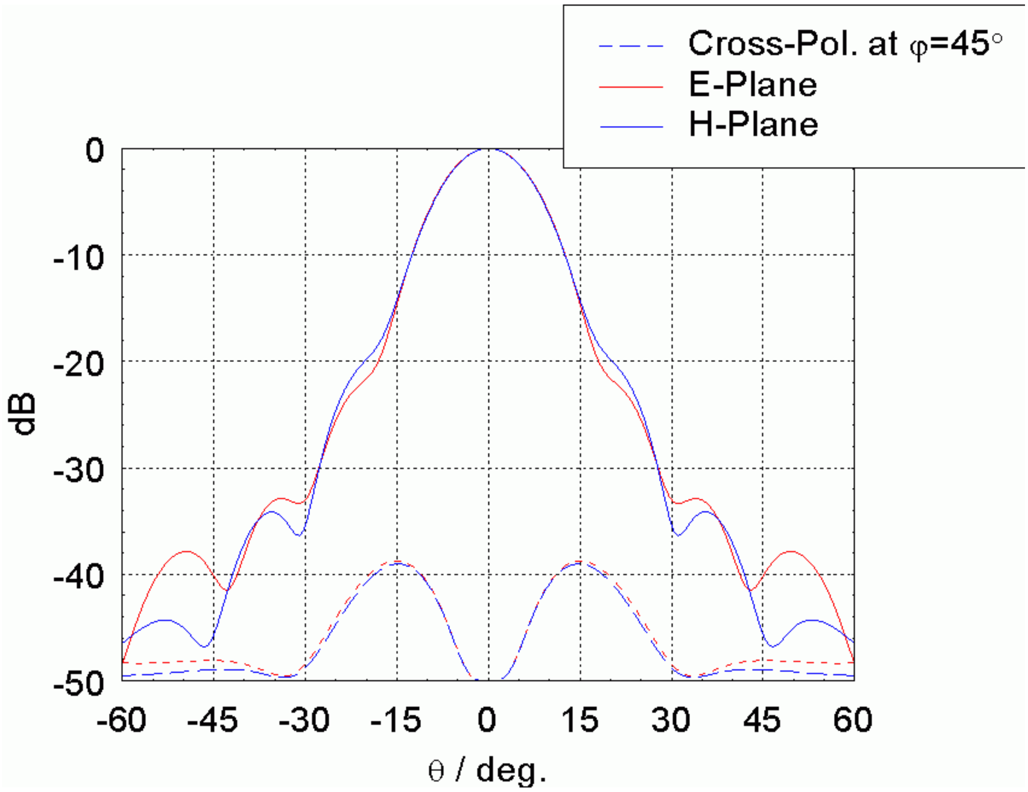

Fig. 3 - E and H field patterns and corresponding cross-polar patterns

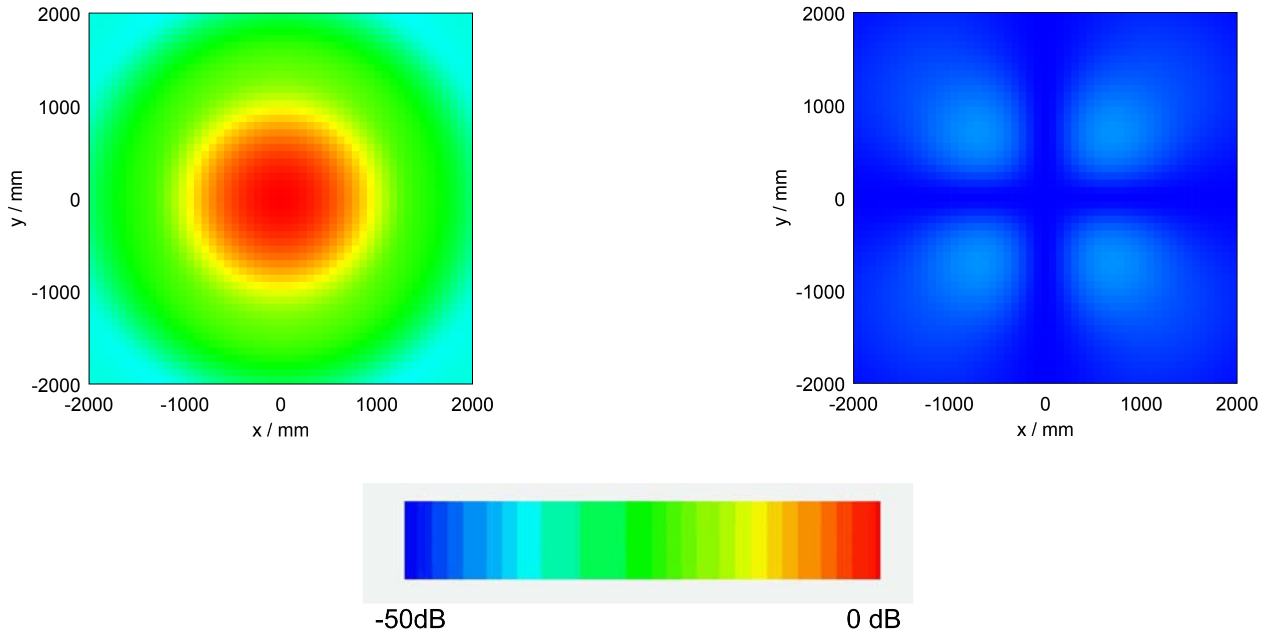

Fig. 4 - Co-polar and cross-polar patterns

Horn optimization is intimately linked with antenna optimization and from these first results a two way analysis process will follow.

2.2.3. Antenna Optical Configuration

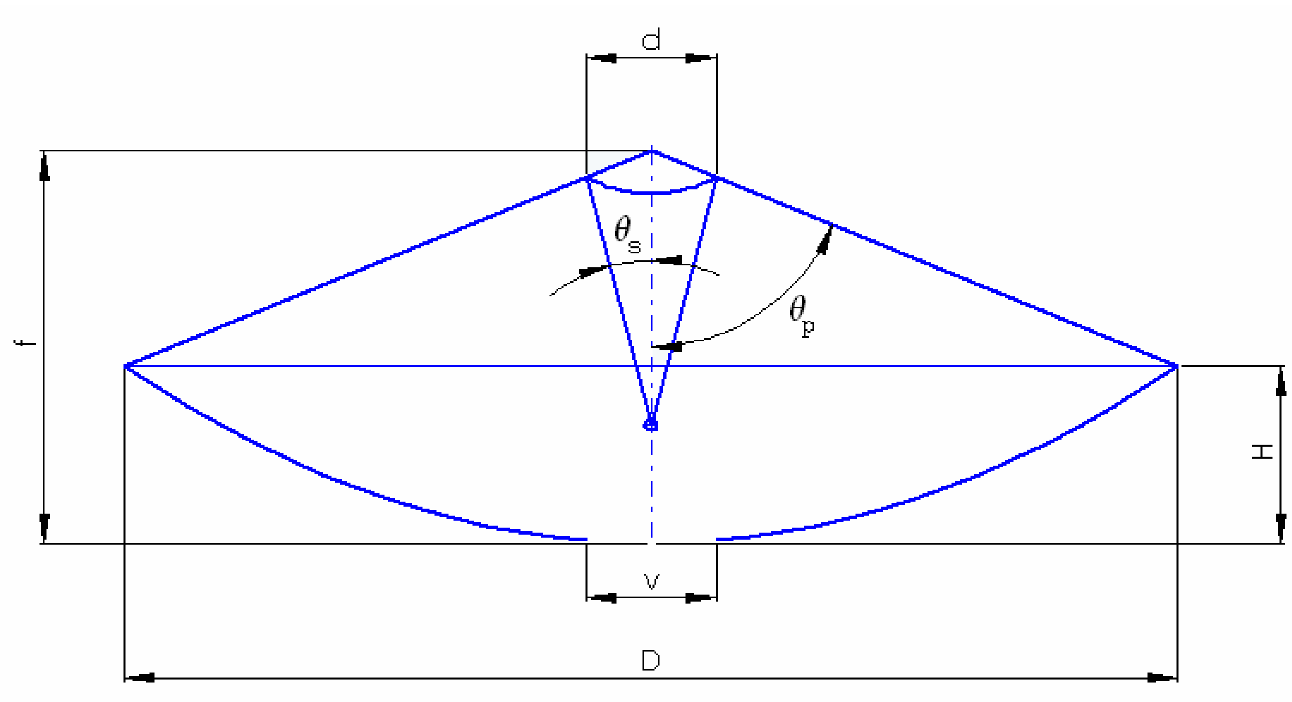

Fig. 5 – Cassegrain focus configuration

Optical Configuration (July 2006)		
D	Primary aperture	8.99 m
f_p	Focal length of primary	3.31 m
	f_p/D of primary	0.37
d	Secondary aperture	1.02 m
	Final f/D	1.99
M	Magnification	5.40
e	Eccentricity of secondary	1.46
θ_p	Primary half-angle of illumination	68.4º
θ_s	Secondary half-angle of illumination	14.3º
2c	Distance between primary and secondary foci	2.19 m
H	Depth of primary	1.53 m
v	Primary inside diameter	1.02 m
	Resolution @ 5GHz	0.47º

2.2.4. Antenna Mechanical Configuration

Mechanical Configuration (July 2006)	
Surface accuracy	0.5mm
Pointing accuracy (≤ 1/10 beamwidth)	3 arc min
Maximum azimuthal velocity	1.4 rpm (4.3º/s)
Maximum elevation velocity	0.35º/second
Azimuth travel	0º-360º
Elevation travel	35º-90º
Working elevation	60º
Configuration	Cassegrain focus, EL-AZ
Weight - Reflector	1900 Kg
Weight - Pedestal	~ 2000 Kg
Environmental (July 2006)	
Operational winds	~20 Km/h
Survival winds	~200 Km/h

2.3. Antenna Analysis

The analysis of the antenna configuration, are currently at the beginning and refinement and optimization are the following step, with some limitation by the available software (GRASP-SE).

Illumination, edge tapper, spillover and efficiency will be the main analysis topics.

Antenna efficiency analysis is needed to determine the real antenna gain and calculate the antenna sensitivity, G/T, for which the value of 40 dB/K will be a reference. For spillover and efficiency, values of 0.01dB and 30%-40%, respectively, will be our references.

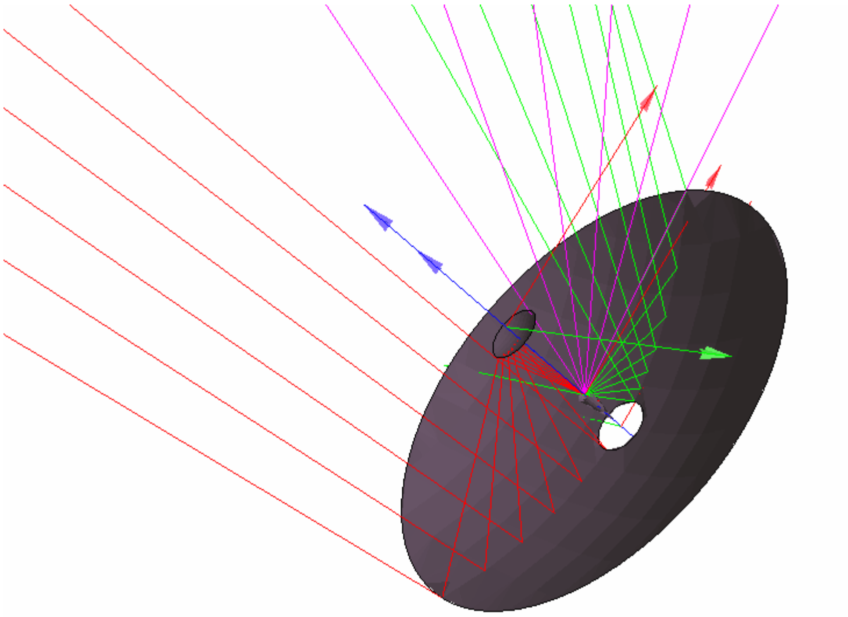

Fig. 6 - Ray paths is used to check the design optical configuration and to determine spillover angles into the horn

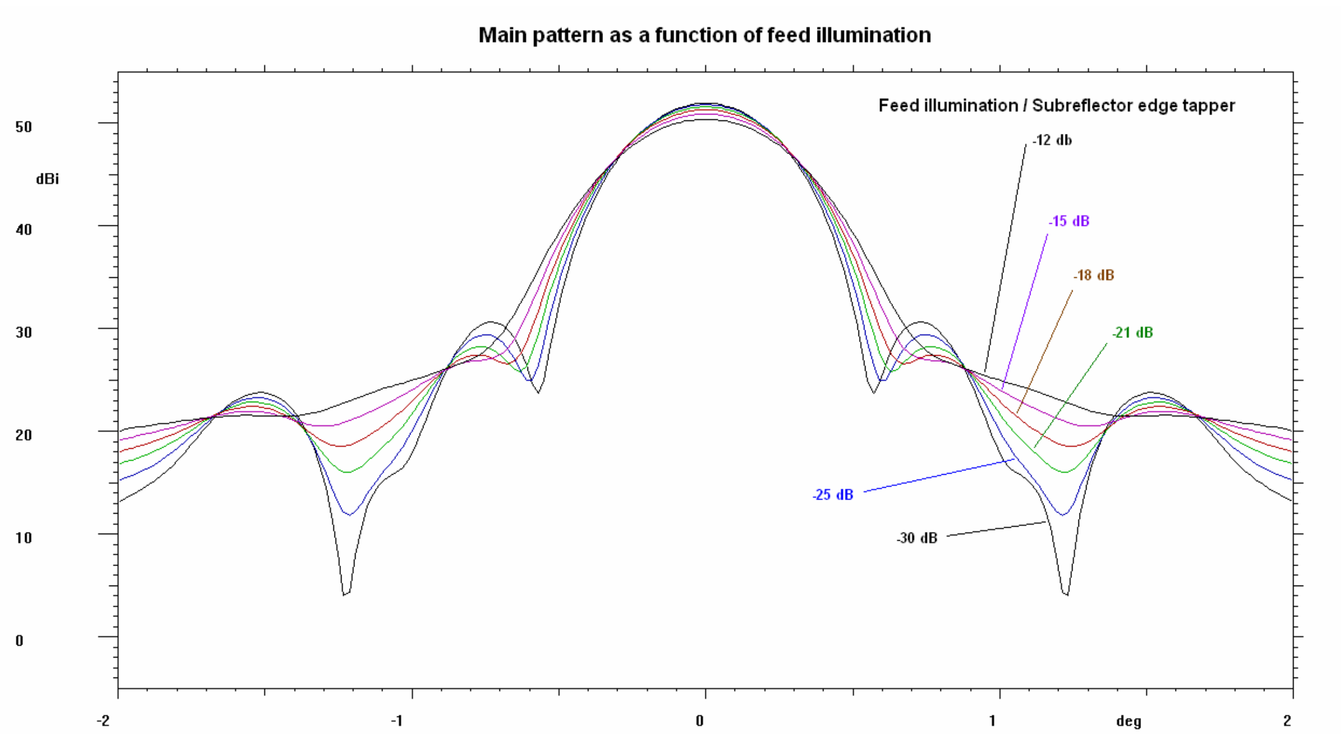

Fig. 7 - Main pattern as a function of subreflector illumination from horn

2.4. Ground Shield

Ground shield purpose is to block direct signal from surroundings to reduce spillover. This will be accomplished by erecting around the antenna an aluminum shield, which will cover the horizon and the line of sight from the feed to the ground. At the moment, civil engineers are working on the proper structure to support the shield.

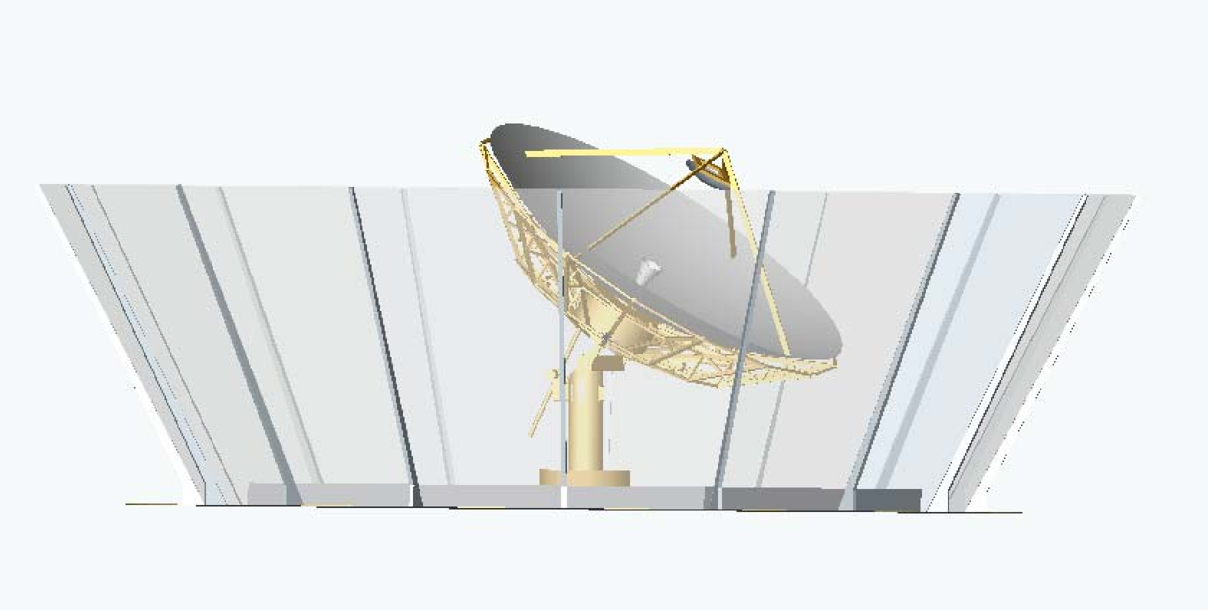

Fig. 8 - Preview of antenna and ground shield setup.

2.4.1. Requirements

- Block horizon and ground line of sight into horn phase center, at operational elevation and main calibration sources elevations
- Reflect sidelobes into the sky
- Reduce diffracted signal from panel edge into the antenna

2.4.2. Ground Shield Configuration

- The panel angle is limited by the antenna 45º elevation position, for which all the interesting calibration sources will be available for the major part of the observing season.
- The length and height is limited by horizon angle for the antenna operational position of 60º elevation.
- The base position of the shield is given by a compromise of ground protection and enough clearance for working around and accessing the antenna.

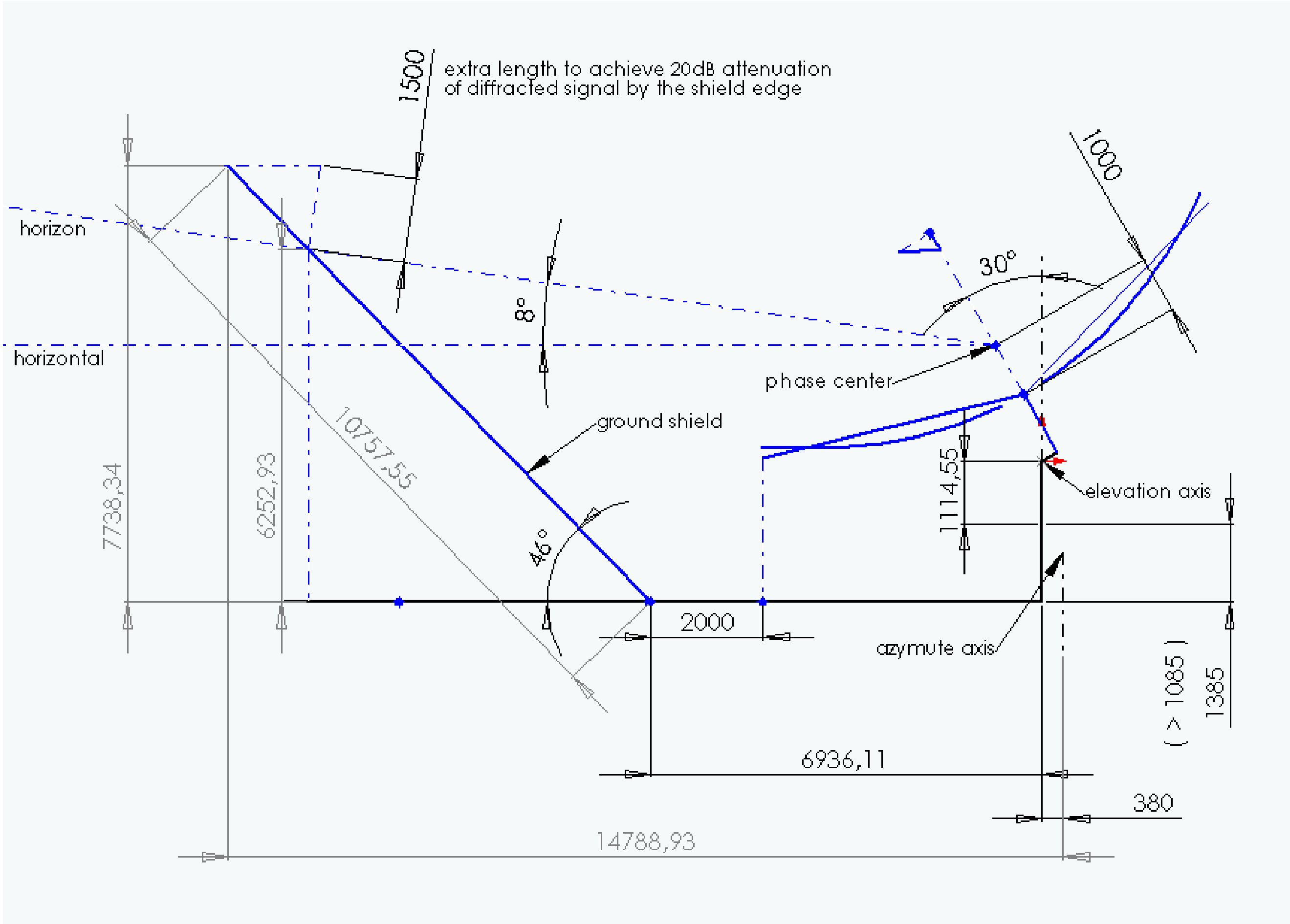

Fig. 9 - Ground shield panel configuration, and antenna at operational elevation

- At this point, aluminum panel will be used, with the necessary care regarding wind loads. Extra support structure from outside will be needed.
- To reduce diffraction spillover, the ground shield length will be extended an extra 1.5 meters, to reduce this signal spill by 20 dB. Additionally, the panel edge will have a smooth curved edge with a radius greater then a quarter wavelength to help minimize this effect.