8925

Customer No/Issue
RO-SES-TN-3017

PROJECT

ROSETTA PLATFORM SUBSYSTEM
HIGH GAIN ANTENNA (HGA)

TITLE

DESIGN DESCRIPTION

	Name	Function	Date	Signature
Prepared :	Hans Ekström	Electrical Design		
	Tomas Göransson	Electrical Design		
	Camilla Svensson	Project Engineer		
	Leif Theodorsson	Mechanical Design		
Checked :	Robert Petersson	Deputy Manager Reflector Antennas		
Authorised :	Göran Forslund	Project Manager		

Distribution
Complete : B2G, T/AF-TG, T/AF-HE, T/AF-CS, T/AF, T/AMT, T/AM-LT, T/AM-MF
Summary :

Rea. Office:
Saab Ericsson Space AB
S-405 15 **Göteborg**
Sweden
Reg. No: 556134-2204

Telephone:
+46 31 735 0000
Telefax:
+46 31 735 40 00

Linköping Office:
Saab Ericsson Space AB
S-53 1 88 Linköping
Sweden

Telephone:
+46 13 18 64 00
Telefax:
+46 13 13 1628

Class :
Contract No :

Host System : Microsoft Word 97 for Windows, SE Macro Rev 3.0
Host File : ...\ROSH\NOT\P-ROSH-NOT-3017_04-SE.doc

SUMMARY

DOCUMENT CHANGE RECORD

Issue	Date	Paragraphs affected	Change information
1	6 Nov 1998	All	New document
2	7 Jan 1999	1	Mechanical design included
		3.1	Crosspolarisation and VSWR
		4.1.1	X-band the design driver
		4.1.2	Sub reflector
		4.2.1	Band separation factor and VSWR
		4.3	Beamwidth replaced by half cone angle
		4.3.1	Symmetry of crosspolarisation and cut information
		4.3.2	Table 4.3.2-I replaced
		4.3.2	Negative margin on sidelobe not essential
		4.3.4	VSWR 1.2 is a goal for the design
		5.4	Text line changed
3	20 Apr 1999	4.3.2	Loss due to conductive paint inserted
3	20 Apr 1999	4.3.3	Crosspolarisation performance at X-band updated
4	15 Sept 1999	3.1	Table 3.1 -I X-band RX RF requirements
		4.2.2	Table 4.2.2-I X-band RX feed requirements Fig. 4.2.2-2
		4.3.2	Table 4.3.2-I X-band RX Gain performance Table 4.3.2-II X-band RX -3 dB half cone angle Table 4.3.2-III X-band RX sidelobe level
		4.3.3	Table 4.3.3-I X-band RX Crosspolarisation

TABLE OF CONTENTS PAGE

1. SCOPE

This document summarises the RF performance and budgets for the Rosetta HGA antenna. It gives also a short presentation of the mechanical design.
The S-band RX and TX functions are obtained from a centre fed single reflector with a combined RX/TX feed placed in the focal point. For the X-band TX function, a dichroic sub reflector is employed in the configuration of a Cassegrainian double reflector system. The polarisation is RHCP.
The performance presented in this report is based on theoretical analyses and BB tests on S-band feed.

2. REFERENCE DOCUMENTS

[RD1] RU-MMB-RS-3 127 High Gain Antenna (HGA) Requirement Specification

3. HGA REQUIREMENTS

3.1 RF requirements

The main functional requirements relevant for the antenna RF design trade off are compiled in table 3.1-I.

	S-band RX	S-band TX	X-band RX	X-band TX	Unit
Frequency band	2.11-2.12	2.29-2.30	7.15 - 7.19	8.40-8.44	GHz
Polarisation	RHCP	RHCP	RHCP	RHCP	
Minimum gain	31.5	31.5	39.0	43.5	dBi
Gain variation over 10 MHz	±0.1	fO.l			dB
Gain variation over 40 MHz	-		±0.15	±0.15	dB
VSWR (spec./today's value)	1.5/1.3	1.5/1.3	1.5/1.2	1.5/1.2	
Side lobe level	-18	-18	-18	-18	dB
Cross polarisation	-22	-22	- 24	-24	dB

Table 3.1-I Main HGA functional requirements

The most important requirement for optimisation of the antenna is the minimum gain. Since only the central ±0.065° to ±0.076° of the main beam will be used, sidelobe level and 3-dB beamwidth are considered as of secondary importance. A trade off to optimise gain at X-band was performed. The gain at X-band was increased by shaping the reflector surfaces.

[RD1] specifies a VSWR of 1.5 for the HGA at both S- and X-band. Agreements have been made to have a VSWR of 1.2 as a design goal. This would be achievable at X-band but more uncertain on S-band.

3.2 Mechanical requirements

For the mechanical design the main design driving requirements are the lowest natural frequencies in stowed and also deployed configuration in combination with the weight requirement and envelop constraints.

For dimensioning of the structure, the interface loads and interface stiffness requirements are the most important.

3.3 Interface requirements

The HGA antenna shall interface to the APM and HRM mechanisms with specific requirements on stiffness and interface loads.

The HRM interface is at three points on the rear side of the reflector.

For the APM, 6 inserts in circular configuration are provided near the reflector edge.

4. HGA ANTENNA PERFORMANCE

The conceptual design suggested in the Requirement Specification is well chosen to meet the functional requirements and the volume constraints. This concept and geometry are with minor changes selected in the design.

To meet the gain requirement with the given volume constraints a centre fed reflector system is preferred. The proposed design gives a number of advantages:

- The dichroic concept with dedicated feeds gives optimum aperture efficiencies
- All components are existing designs, which are qualified or near qualified
- The X-band feed is accessed from behind the main reflector, giving a better waveguide run (shorter, fewer flexible parts)

The S-band RX and TX functions are obtained from a centre fed single reflector with a combined RX/TX feed placed in the focal point. For the X-band TX function, a dichroic sub reflector is employed in the configuration of a Cassegrainian double reflector system. The sub reflector and S-band feed is supported by struts footed in the main reflector.

The design consists of the following main parts:

- Main reflector
- X-band feed
- S-band feed
- Sub reflector
- Sub reflector and S-band feed support
- APM and HRM interface provisions

4.1 Reflector System Design

4.1.1 Configuration and reflector geometry:

A centre fed single reflector at S-band is combined with a Cassegrainian dual reflector system at X-band by means of a dichroic sub reflector. The sub reflector is a sandwich construction transmitting the S-band, hence experiencing only a minor blockage. Metal patterns on the sub reflector surfaces reflect the X-band radiation, operating like an ordinary sub reflector at this frequency band.

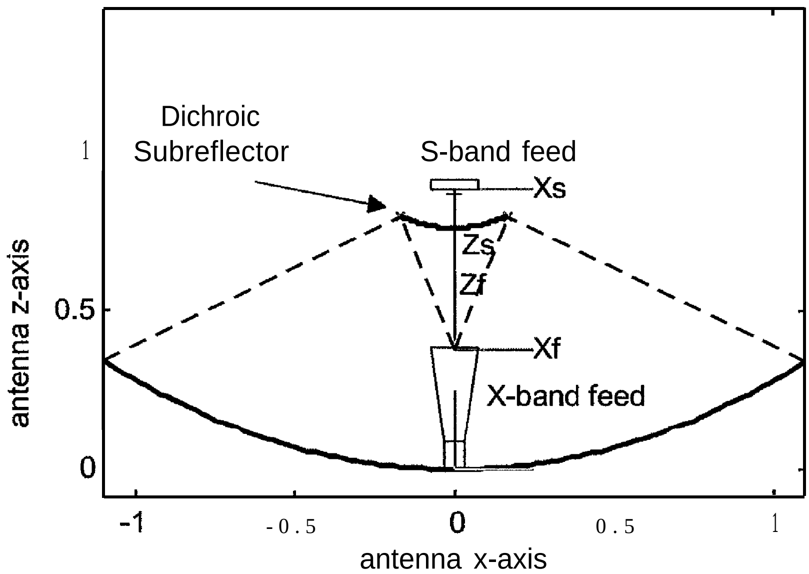

Figure 4.1.1-l HGA configuration geometry

The sub reflector diameter is selected as small as possible in order to limit the central blockage with accompanying loss of gain and increase of the 1:st side lobes. The HGA main geometry parameters are compiled in table 4.1.1-I

Parameter	Value	Unit
Main reflector diameter	2.2	m
Sub reflector diameter	0.34	m
Main reflector focal distance	0.88	m
Focal length to antenna diameter ratio	0.4	
Inter foci length	0.5	m
Sub reflector ellipticity	1.909	
Sub reflector magnification	3.2	
X-band feed subtended half angle	22	dee
S-band feed subtended half angle	64	dee

Table 4.1.1-I Antenna geometry parameters

We have selected a smaller inter foci length than suggested in the Requirement Specification. The reason is that the optimum length of the X-band feed fits better with the available distance above the main reflector. Another advantage is that the sub reflector back radiation is smaller due to the lower feed gain.

In the final trade-off, a gain improvement at X-band is performed by shaping the reflectors. This was a system decision since the gain performance at X-band was marginal and therefore shall X-band be the design driver.

4.1.2 Sub reflector

The dichroic sub reflector consists of two identical skins with printed metallic patterns, separated by a honeycomb spacer. The chosen metallic pattern is an array of metallic ring elements The two skins are separated by a honeycomb structure approximately a quarter of a wavelength at the transmitting S-band, i.e. approximately 30 mm. In case of problems with bulk charging of the sub reflector, the front and back skins will be painted with conductive coating, provided no degeneration of other electrical performance.

The requirement is a dichroic structure that is reflective at X-band and transparent at S-band. The X-band is narrow banded and a single skin with single resonant element is sufficient to meet the reflection requirements at X-band. However, with a single metallic grating the S-band transmission properties will not be fully met. By adding a second metallic grating placed a quarter of a wavelength behind the first grating also the S-band needs will be met. The ring element is chosen due to its excellent properties for circular polarisation.

Dichroic sub reflector is designed with proper phase and amplitude reflection and transmission coefficients obtained from method of moments analyses.

4.1.3 Optimisation and Analyses Procedure

The performance presented in this document is based on analyses and breadboard tests at S-band feed.

The reflector surfaces are shaped to optimise X-band gain using the TICRA software POD. The performances at X- and S-band are analysed using the TICRA software GRASP8. Included in the analyses of the reflector system are:

X-band:

- Potter horn modelled as a dual mode circular waveguide feed with aperture phase reflecting the flare length
- Main reflector analysed by PO
- Blockage from sub reflector analysed by PO
- Direct radiation from the feed is included
- The gain loss and cross polarisation increase due to support struts and sub reflector rim are included in the analyses

S-band:

- Measured far field patterns of the breadboard Patch Excited Cup
- Main reflector analysed with PO

- The gain loss and cross polarisation increase due to support struts and sub reflector rim are included in the analyses

4.2 Feed design

4.2.1 S-band Feed Design

The S-band feed shall have the qualities as compiled in Table 4.2.1 -I. Other non-quantified requirements are low mass and small volume.

Reauirement	Value
Subtended half cone angle	64”
Edge illumination	-11 dB
Band separation factor	1.09
Polarisation, Rx/Tx	LHCP/LHCP
Cross polarisation	<-25 dB
Ohmic loss	<0.2 dB
VSWR	<1.3

Table 4.2.1 -I S-band feed requirements

The S-band feed element is the Patch Excited Cup (PEC) element, specially developed by Saab Ericsson Space for the Artemis program. It exists in a number of versions for different beam widths, frequency combinations and mechanical designs mostly used in mobile communication programs. In Artemis it was used as a fill-in-antenna. Some changes have been done such as weight optimisation and frequency tuning. Example of radiation patterns of the bread-board element is shown in figures 4.2.1-2 and 4.2.1-3.

The PEC antenna element consists of a conical cup with a choke and a patch tower comprising a circular excited disc and a reflector disc. The lower patch is fed by two probes from a stripline feed network located in a box below the cup. The feed network is terminated to provide minimum cross polarisation.

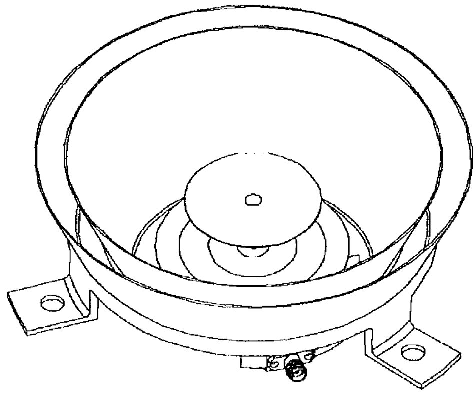

Figure 4.2.1-l The S-band feed element.

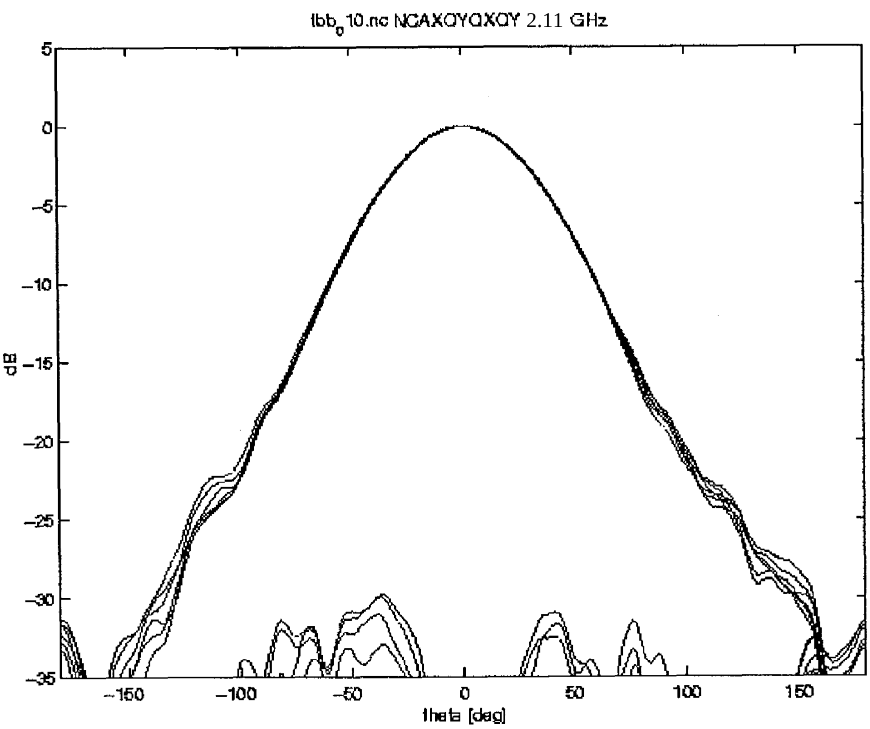

Figure 4.2.1-2 Radiation pattern for the bread-board patch fed cup at 2110 MHZ.

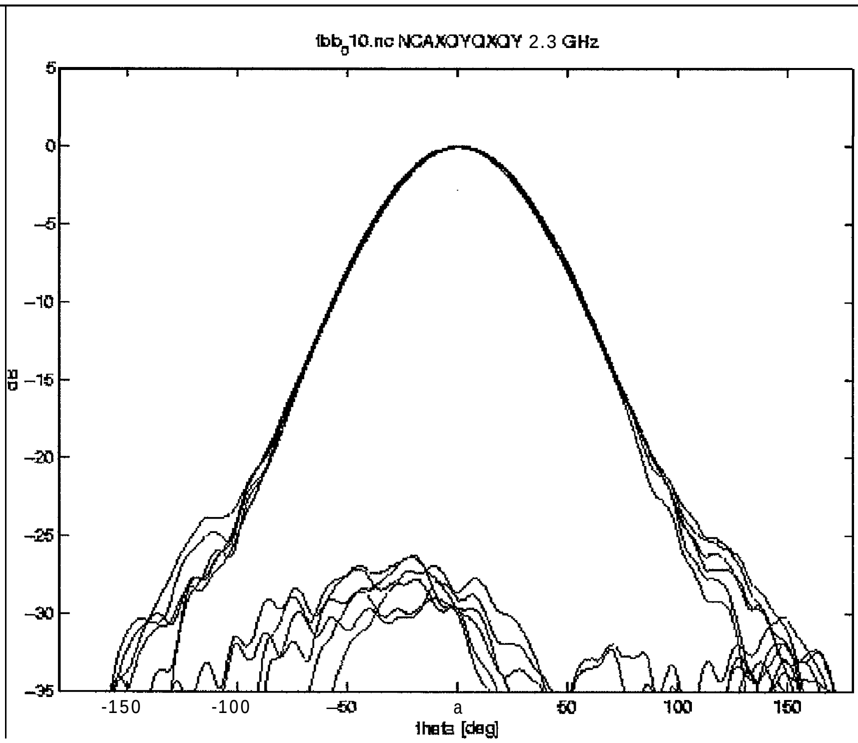

Figure 4.2.1-3 Radiation pattern for the bread-board patch feed cup at 2300 MHz.

4.2.2 X-band Feed Design

The X-band feed has the qualities as compiled in table 4.2.2-I.

Parameter	Value Rx	Value Tx
Subtended half cone angle	22”	22”
Edge illumination	-11.5 dB	-12 dB
Polarisation	RHCP	RHCP
Directivity	18.2 dBi	18.6 dBi
Cross polarisation	<-18 dB	-33 dB
Ohmic loss	<0.2 dB	<0.2 dB
VSWR	<1.3	a.2

Table 4.2.2-I X-band feed requirements

A Potter horn is a suitable design, exhibiting low cross polarisation over the limited frequency band. This type of element lends itself to very accurate analysis using mode matching techniques. The co polarisation radiation pattern in E,H and 45 degrees plane and crosspolarisation in 45 degrees plane is shown in figure 4.2.2-1, calculated as balanced circular modes plus a spherical phase variation corresponding to the flare length.

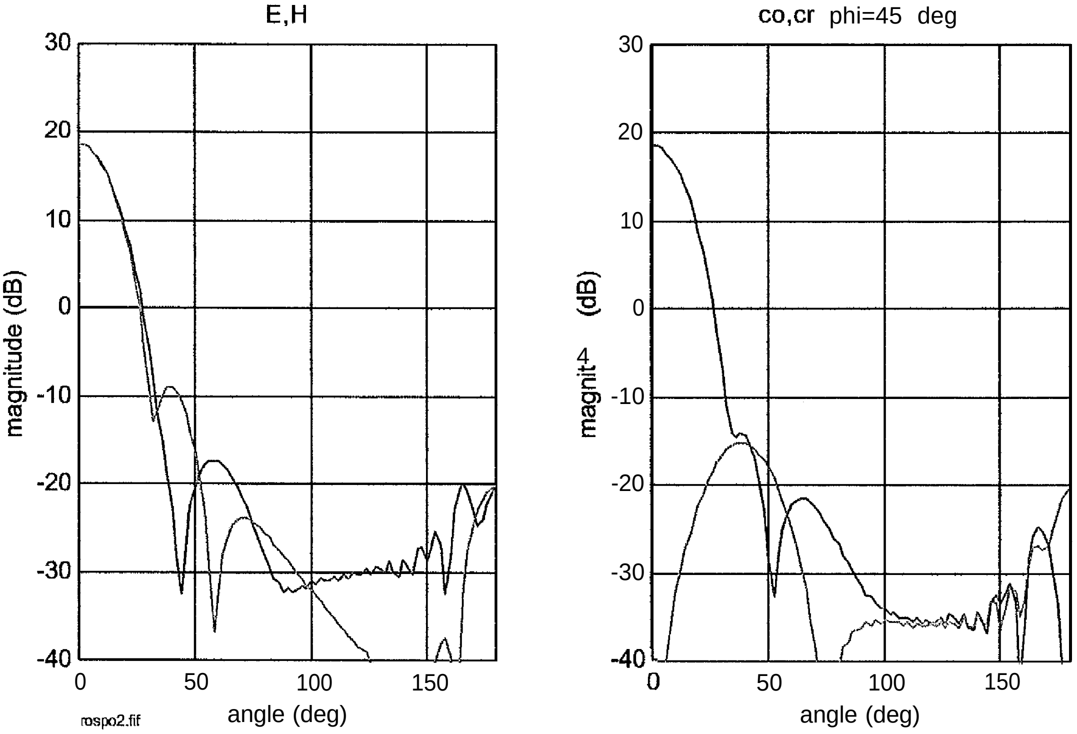

Figure 4.2.2-1 Radiation pattern for the X-band Potter horn at 8.4 GHz.

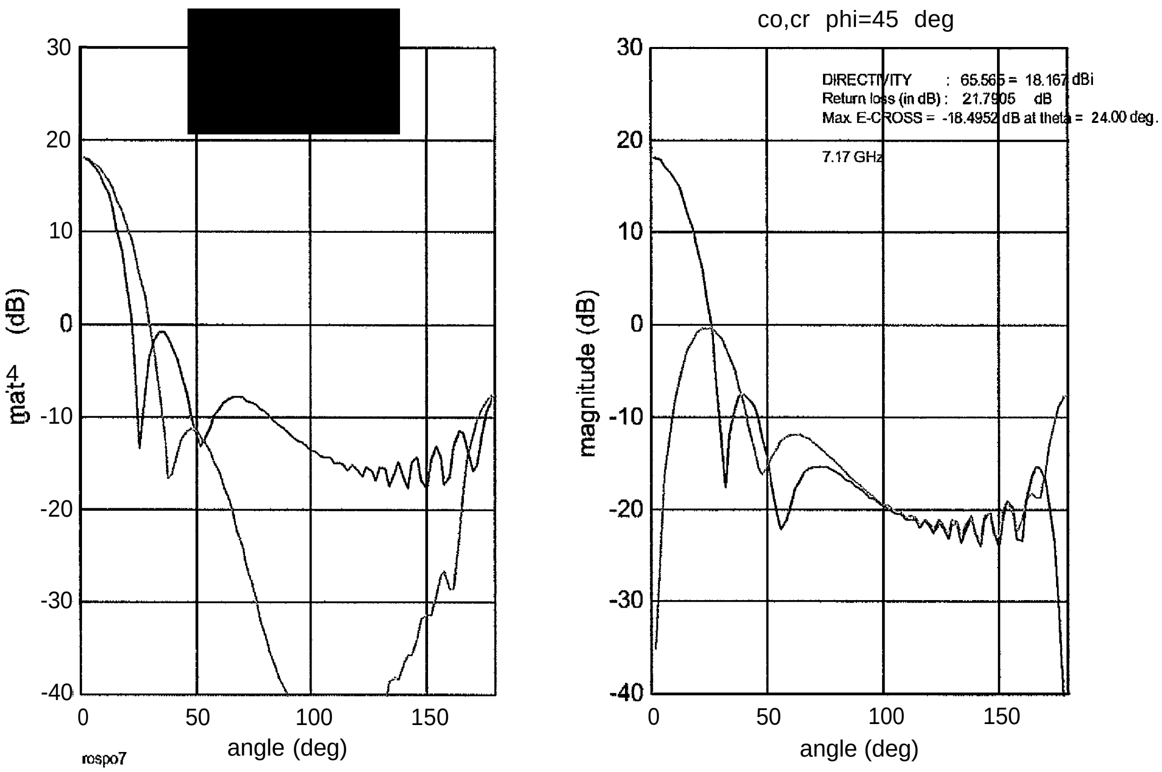

Figure 4.2.2-2 Radiation pattern for the X-band Potter horn at 7.17 GHz.

A septum polariser generates the circular polarisation. The port not used is terminated in order to absorb the signal reflected from the horn and sub reflector, hence reducing the overall cross polarisation;

The feed assembly layout is shown in figure 4.2.2-2

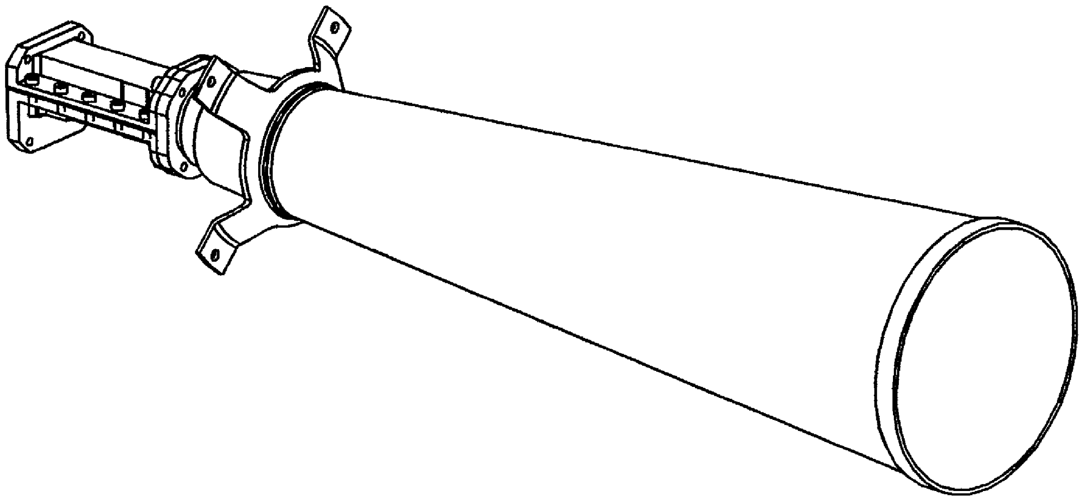

Figure 4.2.2-2 Feed assembly layout

4.3 RF performance reflector system

4.3.1 Radiation Patterns

The analysis is performed as described in section 4.1.3. The co and crosspolar patterns are presented in six different cuts. The S-band co polarisation pattern variation of 0.5 degrees in figure 4.3. l-l and 4.3.1-Z is due to measurement accuracy of feed patterns. The main contribution for the asymmetric crosspolarisation pattern is the feed for the S-band. The struts are also affecting the symmetry on both S- and X-band.

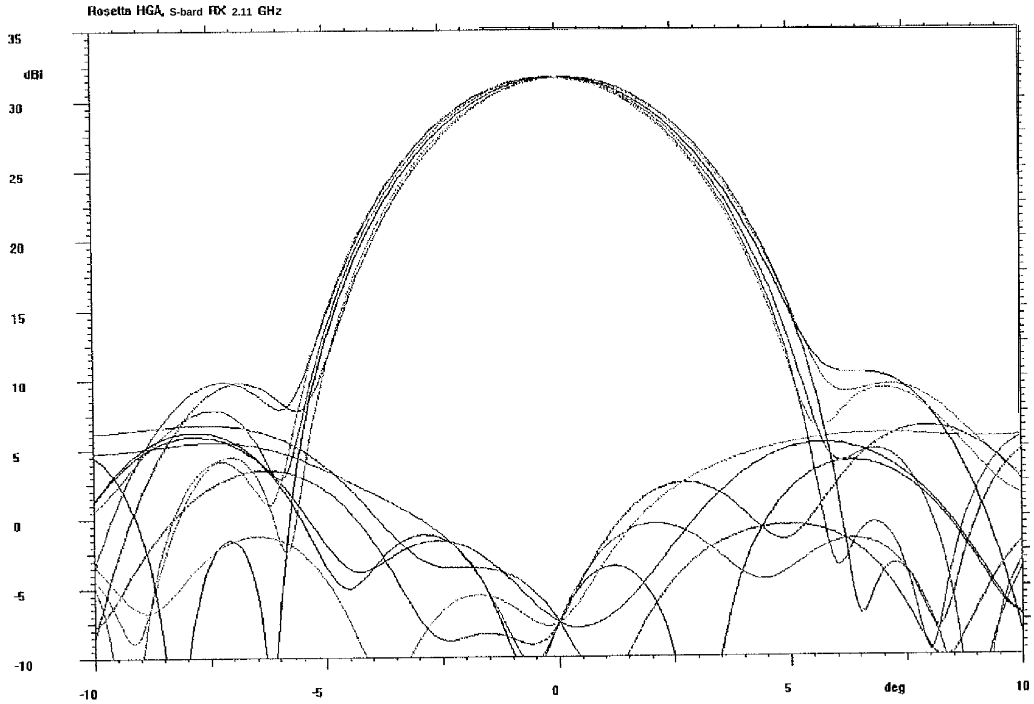

Figure 4.3. l-l

Analysed pattern of the S-band RX frequency. Analysed with measured feed pattern. Cuts: φ = (0°, 30°, 60°, 90°, 120°, 150”).

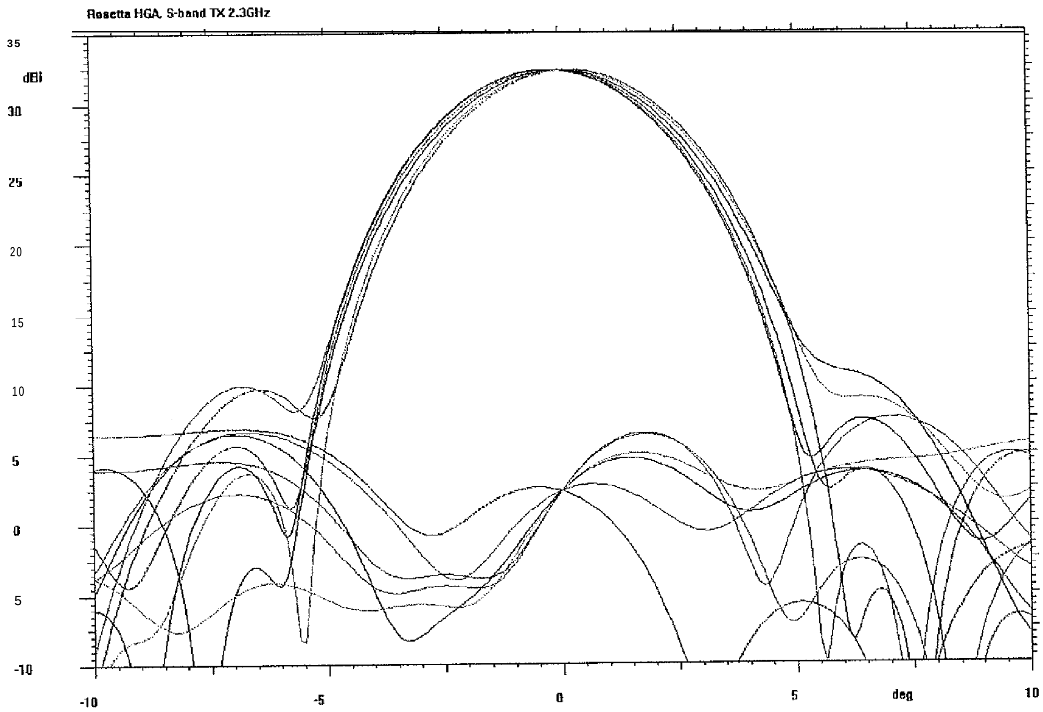

Figure 4.3.1-2

Analysed pattern of the S-band TX frequency. Analysed with measured feed pattern. Cuts: φ = (0°, 30°, 60°, 90°, 120°, 150°).

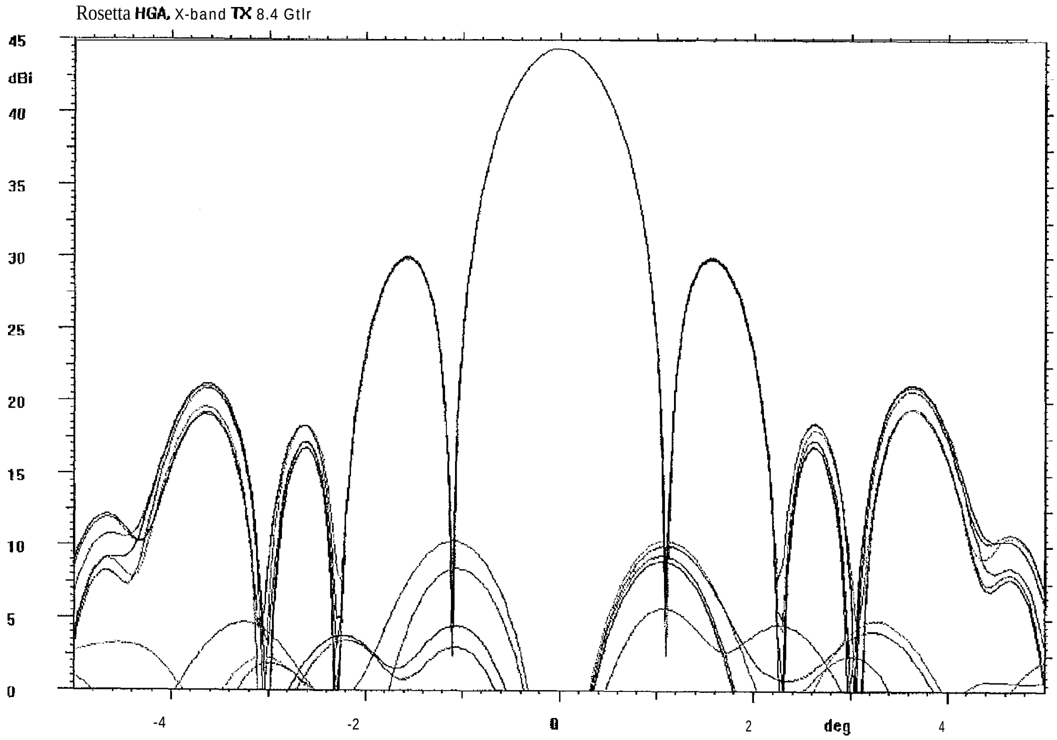

Figure 4.3.1-3 Analysed farfield pattern of the X-band TX frequency. Cuts: $\varphi = (0°, 30°, 60°, 90°, 120°, 150°)$

4.3.2 Gain performance

The gain budgets for S-band TX and RX and X-band TX are shown in table 4.3.2-I.
The gain at X-band is optimised.

	S-band RX	S-band TX	X-band RX	X-band TX	Jnit	Remark
Antenna directivity	31.6	32.4	42.8	44.6	dBi	analysis (S-band: measured feed incl. painted dichroic sub)
Dichroic loss incl multiple reflections between sub and feed	0.2	0.1	2.3	0.2	dB	mainly resistive, test, analysis, estimation. X-band RX non-resonant
Loss due to conductive layer on subreflector	0.3	0.3	0.5	0.5	dB	Estimation (S-band measured)
Edge effects on subreflector	0.1	0.1	included	included	dB	estimation
Strut blockage	included	included	0.3	0.3	dB	analysis
Main reflector loss	0.03	0.03	0.05	0.05	dB	similarity to existing products
Feed loss incl. pol	0.8	0.9	-0.2	0.2	dB	similarity to existing products
Manuf. and thermal distorsions	small	small	0.05	0.05	dB	similarity to existing products
Total gain:	30.2	30.9	39.4	43.3	dBi	
Requirement:	31.5	31.5	39.0	43.5	dBi	
Margi[redacted]	-1.3	-0.6	0.4	-0.1	dB	

Table 4.3.2-I Gain budget. S-band: Measured feed pattern. X-band: Analysed feed pattern

Loss due to conductive layers on subreflector

X-band: estimation from reflection measurement of a flat plate breadboard

S-band: from measurement of feed gain including dichroic subreflector with and without paint.

The conductivity is between 0.1 – 10 MΩ/square.

The gain variation with frequency is calculated to be 0.04 dB/40 MHz at X-band and 0.04 dB/10 MHz at S-band. The requirement is 0.15 dB/40 MHz at X-band and 0.10 dB/10 MHz at S-band.

The 3 dB half cone angle is analysed and presented in table 4.3.2-II. The half cone angle is not optimised and it is decreased due to gain optimisation.

	S-band Rx	S-band Tx	X-band Rx	X-band Tx	Unit
3 dB half cone angle	2.23	2.05	0.57	0.48	deg
Requirement	2.25	2.1	0.57	0.57	deg
Margin	-0.02	-0.05	0	-0.09	deg

Table 4.3.2-II 3 dB half cone angle

The levels and the angle positions of the sidelobes is analysed and presented in table 4.3.2-III. The negative margin on X-band is not considered essential since only TX-operation.

	S-band Rx	S-band Tx	X-band RX	X-band Tx	Unit
Sidelobe level	-22	-22	-14	-14	dB
Reauirement	-18	-18	-18	-18	dB
Margin	4	4	-4	-4	dB
Angle position of sidelobe	7	7	1.5	1.5	deg

Table 4.3.2-III Sidelobe levels and positions

4.3.3 Crosspolarisation performance

The crosspolar isolation at S-band is presented in boresight and at an angle of 0.5 degrees which correspond to the 3 dB half cone angle at X-band and also at the 3 dB half cone angle at S-band. The X-band is presented at the 3 dB half cone angle. The result shows out of spec. values at S-band TX for the 3 dB half cone angle. The values are presented both as crosspolar isolation and axial ratio in table 4.3.3-I.

	S-band Rx boresight	S-band RX (0.5 °)	S-band RX (3 dB)	S-band TX boresight	S-band TX dB(0.5°)	S-band TX (3	Unit
Analysed crosspol including feed and strut/sub rim interference	-39	-35	-26	-30	-27	-23	dB
Dichroic effects	-35	-35	-35	-35	-35	-35	dB
Polariser/Feed network							dB
Total crosspol:	-35	-29	-23	-26	-24	-21	dB
Requirement:	-22	-22	-22	-22	-22	-22	dB
Margin	13	7	1	4	2	-1	dB
Axial Ratio	0.3	0.6	1.2	0.9	1.1	1.5	dB
Requirement	1.4	1.4	1.4	1.4	1.4	1.4	dB

	X-band RX (3 dB)	X-band TX (3 dB)	Unit
Analysed crosspol including feed-horn and strut/sub rim interference	-28.7	-36.8	dB
Dichroic effects	-43	-43	dB
Polariser/Feed network	-30	-33	dB
Total crosspol:	-22	-27	dB
Requirement:	-22	-22	dB
Margin	0	5	dB
Axial Ratio	1.4	0.8	dB
Requirement	1.4	1.4	dB

Table 4.3.3-I Crosspolar isolation performance budget in boresight and at the 3 dB half cone angle of the S- and X-band.

4.3.4 VSWR

The VSWR at X-band will be below 1.2.

The S-band Patch Excited Cup feed element used for the Artemis program had a VSWR of 1.3. 1.2 is a goal for the design used in this program.

5. MECHANICAL DESIGN

The mechanical design of the Rosetta High Gain Antenna is characterized by low weight, high structural stiffness and proven manufacturing processes. The overall design and the main parts of the HGA reflector and feed systems are shown in figure 5-1.

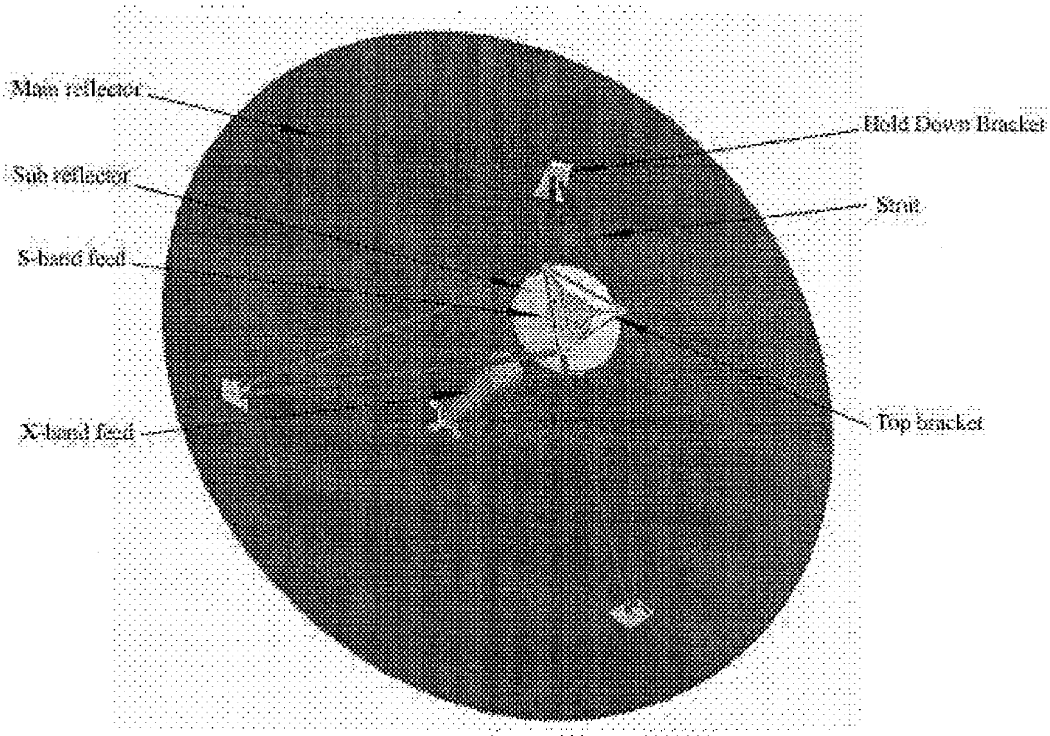

Figure 5-1 High Gain Antenna reflectors and feeds system.

5.1 Main reflector

The main reflector has a projected diameter of 2.2 m and it has a rotationally symmetric shape. The reflector is a light weight thermally stable sandwich design. The skins utilise high modulus carbon fibre reinforced plastic (CFRP). The distance material is a CFRP honeycomb.

A rear back up structure is needed due to the size of the main reflector in order to optimise the weight and stiffness properties. Sandwich panels with CFRP laminates and aluminium honeycomb are used. The rear structure is shown in figure 5.1-1.

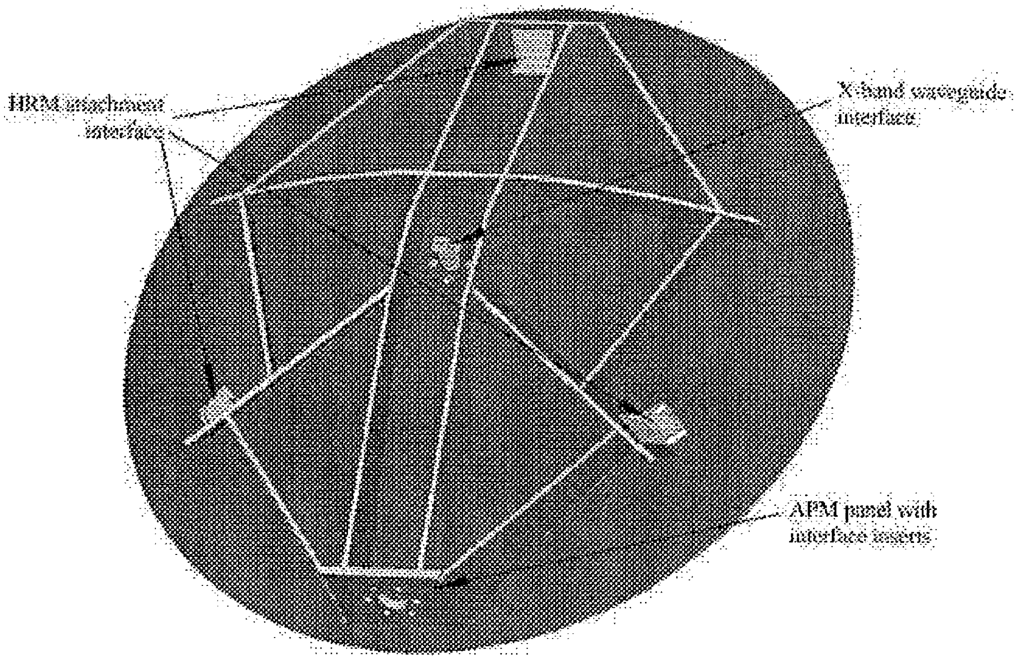

Figure 5. I-l High Gain Antenna back structure and attachments.

5.2 X-band feed

The X-band antenna feed is a light weight thin walled aluminium horn. It is attached to inserts in the main reflector and mounted through a centre hole in the main reflector. All components of the feed chain are made in aluminium. See figure 4.2.2-2.

5.3 S-band feed and top bracket

Simple and safe manufacturing methods have led to a basically throughout aluminium design, i. e. all major parts are made from aluminium. Necessary dielectric parts are minimised with respect to number and size. Also the number of joints necessary for the assembly are minimised.

The feed is attached to a top bracket (see figure 5-l) which is attached to the six struts. The top bracket function is also to hold the struts together and to fix their positions.

5.4 Sub reflector

The sub reflector is dichroic with reflection for the X-band and transmission for the S-band. It is made of quartz fibre reinforced plastic (QFRP) laminates and QFRP honeycomb. Thin copper ring elements are placed on the laminate inner surfaces.

The sub reflector is attached to the Top bracket, close to the struts upper end.

5.5 Mechanicat interface

The antenna is in stowed configuration attached to the satellite through three hold down brackets and one antenna pointing mechanism (APM). The hold down brackets are at the antenna interface attached to Hold and Release Mechanism (HRM) which will detach the antenna into its deployed configuration. The antenna APM and HRM interfaces can be seen in figure 5. l-l.

5.6 Grounding

Grounding to prevent electrostatic discharge is used for all metallic parts, except for the printed metallic ring elements of the dichroic subreflector. The feed chain is assumed grounded through the feed waveguides. Metallic parts are interconnected through a grounding network and a grounding lug is provided,

5.7 Thermal design

The all CFRP sandwich construction implies much less thermal distortions than with traditional aluminium honeycomb and the need for thermal protection is limited.

The rear side of the main reflector are foreseen covered with MLI.

5.8 Mass budget

The High Gain Antenna total mass is 13,6 kg. The mass budget is shown in table 5.8-I.

Title	Mass per Unit (g)	Number of Units	Total Mass (g)
S-Band Antenna Assy (including top bracket)	430	1	430
Sub Reflector Top Assy	465	1	465
Strut Assy	120	6	720
Main Reflector Top Assy (including back structure 3980 g)	10990	1	10990
Feed Horn Top Assy	995	1	995
High Gain Antenna Top Assy		1	13600

Table 5.8-I. Mass budget for the HGA.