ESA's 35-Meter Deep Space Antennas at New Norcia/Western Australia and Cebreros/Spain[1,2]

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Abstract— This paper describes the technical characteristics of ESA's Deep Space Antenna (DSA) installed in New Norcia/Western Australia, its second DSA under contract to be erected in Cébreros/Spain and the overall scenario with a third DSA, establishing a European Deep Space Network (EDSN).

The need to built an ESA Deep Space Antenna in support of deep space and high elliptical-orbit missions, was triggered in 1997 by the ESA mission model, which could not be supported by the ESA 15m network, nor by spare capacity from NASA/DSN or other Space Agencies, also in view of the worldwide flotilla of missions to Mars planned in the 2003 to 2011 timeframe. Taking into account both existing and planned facilities, it was determined in 2001, that a second DSA is required to complement the first DSA. The need of a third DSA, to establish an EDSN as scoped by the Network of Centres initiative is currently under investigation.

The first 35 meter parabolic reflector antenna includes a full motion turning head pedestal with a Beam Wave Guide (BWG) feed system, cryogenically cooled S-and X-band Low Noise Amplifiers (LNAs), 20 Kilowatt S- and X-band transmitters and all other supporting equipment of the front-end. The second antenna is copy in many areas, will however have only X-and Ka-band frequencies. These antennas are amongst the largest in the world used for TT&C applications and represent the jewel in the crown of the European Space Operations Centre (ESOC) ground station network.

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1. INTRODUCTION

1.1 Definitions

Deep Space (DS) missions are defined going further than 2 million km from Earth, where the typical distance is above 1 AU (150 million km). Allocated frequency bands for Deep Space operation according ITU are:

- S-band: 2110-2120 MHz uplink, 2290-2300 MHz downlink
- X-band: 7145-7190 MHz uplink, 8400-8450 MHz downlink
- Ka-band: 34.2-34.7 GHz uplink, 31.8-32.3 GHz downlink

So far only NASA DSN (Deep Space Network, operated by JPL) supported DS missions.

1.2 Why ESA Deep Space Network (EDSN)?

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[2] IEEEAC paper #1294, Version 2, Updated December 3, 2003

- The American (NASA-JPL) DSN is overloaded and has little resources in Southern hemisphere. Therefore it is difficult to support the future ESA Deep Space missions with existing resources.
- Radio Science experiments and critical manoeuvres require the use of more than one station a the time

Current ESA mission model

ESA Missions	*Launch date*	*Max distance*
Mars-Express	June 2003	Mars
Rosetta	February 2004	6.25 AU
Venus-Express	October 2005	Venus
Bepi-Colombo	September 2012	Mercury

- A European network, if properly designed, will complement the American one
- ESA will become independent from DSN support for core missions
- ESA is enabled to support NASA missions

1.3 ESA Deep Space Scenario and plans

In August of 1998 ESA's Space Operations Centre (ESOC) awarded the contract for the first 35-meter Deep Space Antenna including the active front-end equipment. The antenna was finally commissioned in autumn 2002 and is operational now. One of the first important missions is ESA's Mars Express [2], currently on the way to Mars and Rosetta program [1] in which a spacecraft, launched in 2004, will rendezvous some 10 years later with the comet. The ground station at New Norcia will keep contact with the spacecrafts including commanding, reception and tracking. Rosetta will be up to 930 million kilometers from the Earth, more than six times the distance from the Earth to the sun. The entire mission lifetime is scheduled for 12 years.

The contract for the second antenna was awarded in February 2003 and it shall be ready by September 2005 in support of the Venus Express project.

The DSA1 and DSA2 network may be complemented by a third station in the future, if dictated by the ESA mission model, commensurate with the available resources.

2. DSA1 Front-end description

The system block diagram of the front-end of the first antenna is given in Figure 1 showing the mechanical/structural elements, Beam Wave Guide (BWG), servo, uplink and downlink chains, as well as other auxiliary subsystems. The major elements are briefly described in the subsequent sections. The second antenna will not include S-band anymore, but will have Ka-band reception instead and will be prepared for Ka-band transmission. The following description applies only for the first antenna.

2.1 Downlinks

The S-and X-band downlinks have identical configurations. For each band, there are two Low Noise Amplifiers (LNA), each connected directly to the receive arm of each diplexer followed by a dual channel downconverter.

The outputs of the downconverters are further converted to 70 MHz and then digitally processed in the Intermediate Frequency Modem System (IFMS), which is part of the back-end and not shown here.

2.2 Uplinks

The S- and X-band uplinks are both arranged as a primary chain and a backup chain. The primary chain has a 20 kW HPA while the backup chain has a 2 kW HPA. Two upconverters are used for each band and equipment provides for redundancy switching. This configuration allows transmission with either LHC or RHC polarization in a given band. The BWG including the dichroic mirror provides the capability to transmit 20 kW of power in S-band and in X-band simultaneously.

2.3 Servo Drive

The servo drive subsystem consists of the Antenna Control Unit (ACU), the interlock system, the servo amplifiers, motors and encoders, the servo interfaces to the Front End Controller (FEC) for receiving commands and program track data and for providing status information. The azimuth and elevation axes are equipped with anti-backlash drive units, using brushless motors and high-resolution optical encoders. The servo amplifiers and the entire control loop are fully digital and interconnected by a local bus system.

2.4 Monitoring and Control Subsystem

The Monitoring and Control Subsystem provides remote monitoring and controlling for the whole front-end. It consists of Front-end controller and a data acquisition unit.

2.5 Auxiliary Subsystems

In addition to the equipment and subsystems described in the preceding sections, the antenna contains several auxiliary subsystems as ranging calibration. Test subsystem, Frequency reference, Air conditioning, chilled water, Wave Guide pressurization and power distribution.

2.6 Upgrade options for New Norcia

- *Ka-band*

As the antenna is mechanically prepared for Ka-band frequencies (32 GHz), it can be easily upgraded for Ka-band reception by replacing one mirror by a dichroic mirror and adding the Ka-band downlink. Some more calibrations and correcting actions will also be required in the servo to improve the pointing error. Also an option for Ka-band monopulse autotrack can be implemented.

- *Movable subreflector*

Currently the antenna is optimized at 10 deg elevation and is not improving G/T by going to higher elevations, as the subreflector sag is impacting the performance. This drawback will be corrected by upgrading the antenna with a movable subreflector early 2004. This could initially not be done because of budget constraints, but it was already mechanically prepared for it.

3. ANTENNA PERFORMANCES

3.1 RF Performance

The requirement for communicating with a spacecraft over these long distances implies very stringent Radio Frequency (RF) requirements on the ground station antenna system.

Therefore the earth station must provide sensitive receivers and powerful transmitters coupled to a high gain antenna to allow reliable communications with the spacecraft over these great distances.

Table 1 Key RF Performance for DSA 1 and DSA 2

Requirement	S-Band Only DSA 1	X-band DSA 1 +2	Ka-band DSA 1 =option DSA 2 =baseline	Dim
Receive Frequency Band	2200 – 2300	8400 – 8500	31800 – 32300	MHz
G/T including Program Track Error at 10 deg elevation	≥ 37.5	DSA 1: ≥ 50.1 DSA 2: ≥ 50.8	DSA 1: ≥ 56 DSA 2: ≥ 55.8	dB/K
Receive Polarization	Left and Right Hand Circular Simultaneously			
Transmit Frequency Band	2025 – 2120	7145 – 7235	DSA 2 only: 34200 – 34 700 (Option)	MHz
Max. EIRP	≥ 97	≥ 107	≥ 100.7	dBW
Transmit Polarization	Left or Right Hand Circular – Selectable			
Sidelobe envelope (Transmit and Receive)	**DSA 1**: 1st sidelobe: 13 dB below main beam. Further sidelobes: (29 - 25 log ϕ) dBi for ϕ ≤ 48 deg; -13 dBi for ϕ ≥ 48 deg; **DSA 2**: 1st sidelobe: 13 dB below main beam. Further sidelobes: (32 - 25 log ϕ) dBi for ϕ ≤ 48 deg; -10 dBi for ϕ ≥ 48 deg			

3.2 Mechanical and Servo Performance

The servo subsystem is required to operate in program track mode with time-tagged azimuth and elevation coordinates being supplied from a precise computer generated orbital model.

Table 2 Mechanical and Servo Performance of DSA 1 &2

Equipment	Performance			Dim
Main Reflector Diameter	35			Meter
Main reflector accuracy	≤ 0.3			mm, rms
Subreflector accuracy	≤ 0.2			mm, rms
Beam waveguide accuracy	≤ 0.2			mm, rms
	Azimuth	Elevation		
Travel Range	DSA 1: 0 to 480 DSA 2: 0 to 540	0 to 90		deg
Slew Rate, both axes	DSA 1: ≥ 0.4 DSA 2: ≥ 1.0			deg/sec
Acceleration, both axes	≥ 0.4			deg/s^2
Pointing Error [3]	S-band: ≤ 26	X-band: ≤ 11	Ka-band ≤ 6	mdeg
Operational Wind	DSA 1: 45 constant gusting to 60 DSA 2: 50 constant gusting to 70			km/h
Temperature	DSA 1: 0 to 50 DSA 2: -20 to 50			°C

[3] Different compensation methods for the different bands

Figure 1 – Deep Space Front-End Blockdiagram

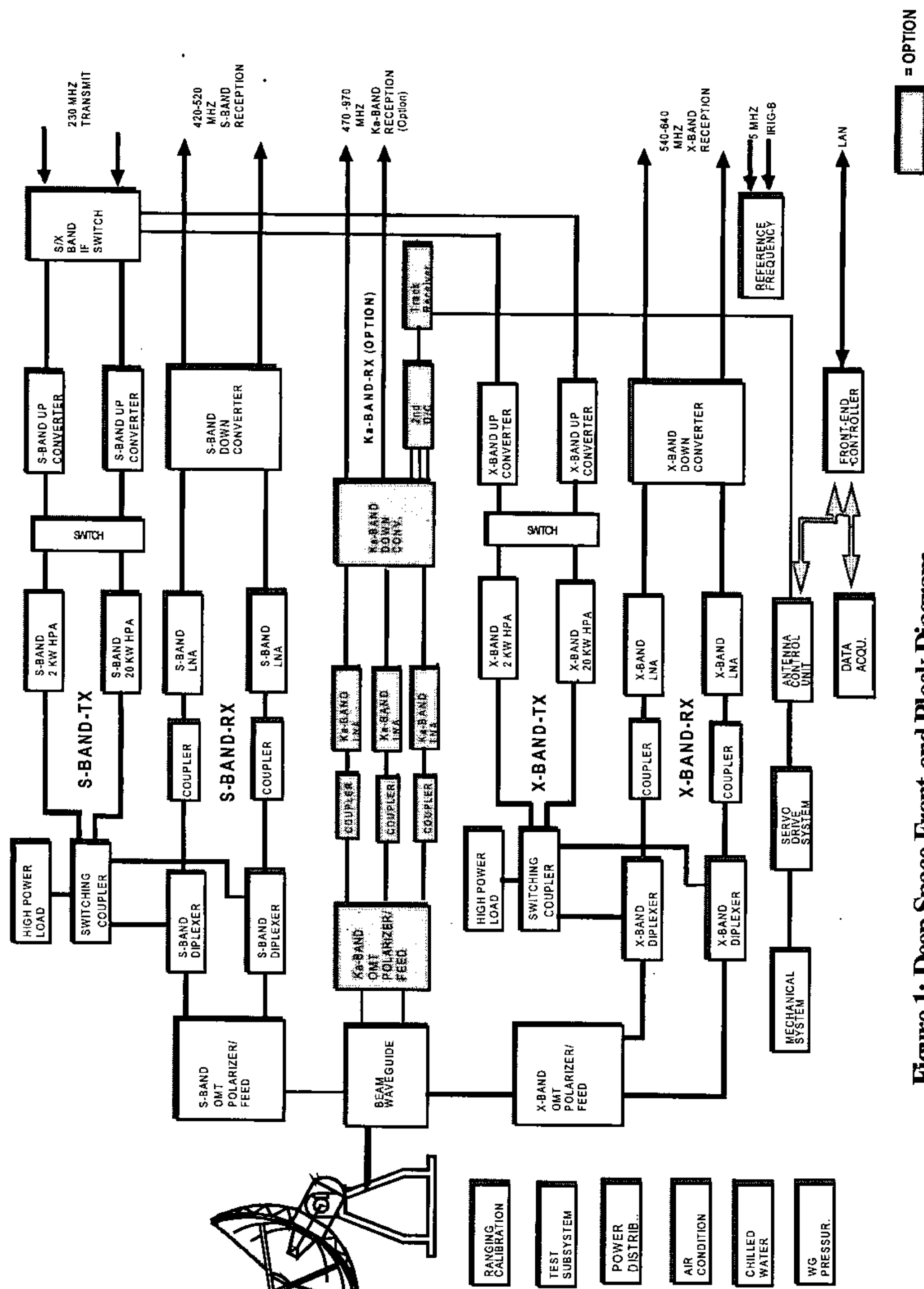

Figure 1: Deep Space Front-end Block Diagram

4. ANTENNA DESIGN

4.1 Overall Conceptual trade-offs

Before the implementation phase a competitive study was performed with industry, which brought the following study results:
To obtain the required G/T for the downlinks a parabolic reflector of at least 35 meters in diameter is required combined with cryogenically cooled LNAs. Further analysis indicated that transmitter amplifiers capable of producing 20kW of output power were required to meet the EIRP requirements of the uplinks.

RF Tradeoffs between standard Cassegrain antenna, and an axis centered beam waveguide (BWG) approach, determined that the BWG configuration was technically superior as well as being cost and schedule effective. The major advantage of the BWG concept is that no rotary joints or long waveguide runs are needed at the antenna axes. This is an important aspect in view of the possible passive intermodulation related to it. The BWG design allows for optimization of illumination, efficiency, gain and in particular, sidelobe performance for each band. It permits simultaneous operation in all specified bands. With this concept all critical electronic equipment like High Power Amplifiers (HPAs) and cryogenic cooled LNAs can be located in the equipment room at ground level, easing operation and maintenance activities.

Mechanically tradeoffs between a Turning Head (TH) and a Wheel and Track (WT) pedestal design, determined that TH approach was technically superior. The TH structure provides a better reflector surface and pointing accuracy in all operating conditions including wind disturbances and minimizes thermal effects compared to a WT approach.

4.2 BWG and RF Feeds Layout

The combined axis centered BWG and TH design configuration selected from the trade-offs is shown as a conceptual layout in Figure 2 (DSA 1 concept). The elements of the BWG, i.e. feeds and mirrors are shown relative to the azimuth and elevation axes and the subreflector and main reflector. The ray optics with 6 mirrors for S-band and 7 mirrors for X-band are shown labeled M1 through M7 (not shown here).

The first mirror M1 rotates in azimuth and elevation with the main and subreflector. A plane surface is used to ensure an imaged feed pattern that is independent of the elevation of the antenna. Mirrors M2 and M3 are parabolas. M4a is again a plane mirror in order to ensure an imaged feed pattern that is independent of the azimuth of the antenna. This mirror can be replaced by a dichroic mirror, when Ka-band functionality is implemented and a plane mirror M4b will be added. A Ka-band feed will then be placed in the focus of M4b. The Ka-band feed will contain elements similar to the other two feeds except diplexers are not included since transmission at Ka-band is not a requirement. M5 is an ellipsoid in order to allow smaller feedhorns in the pedestal room. M6 is a plane dichroic mirror that reflects in S-band and is transparent in X-band. M7 is a plane reflector used for X-band only.

Fig. 3 shows the mirror, feed and equipment configuration in the antenna basement. The largest mirror is M5, which reflects the energy coming from the long BWG through the elevation and azimuth axis. The mirror with the hole represents the dichroic M6, transparent for X-band and reflecting for S-band. The S-band energy goes to the S-band LNA and S-band transmitter, decoupled by a diplexer. The same applies for X-band, after the energy passes through the dichroic and reflected by M7.

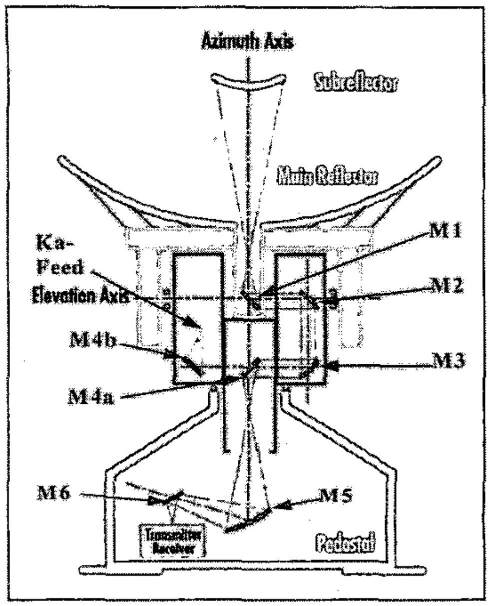

Figure 2 - Layout of BWG Design in Turning Head Pedestal

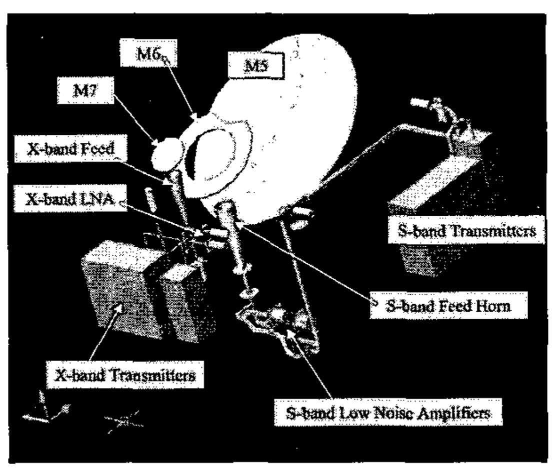

Figure 3 - Mirror, feed and equipment configuration in the basement (Sketch)

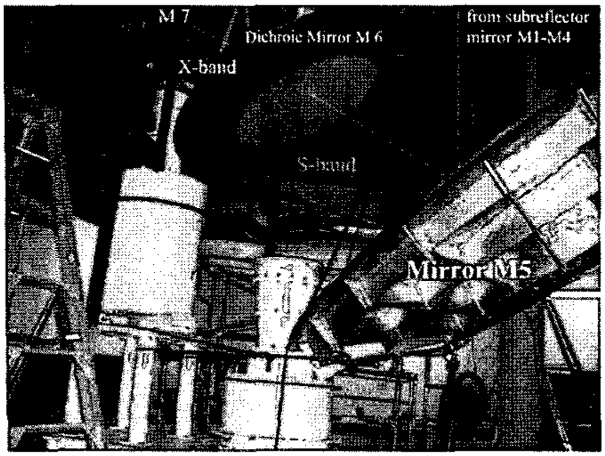

Figure 4 - Mirror, feed and equipment configuration in the basement (actual)

The S-and X-band feeds are each comprised of a broadband corrugated horn, a mode launcher, a 90-degree circular motorized polarizer and an orthomode transducer with two rectangular waveguide input/output ports; one for each sense of circular polarization. The polarizer can be rotated 90 degrees via circular waveguide rotary joints to change the polarization associated with each port. A diplexer on each port provides isolation between the transmit and receive signals for the corresponding frequency band to allow simultaneous transmit and receive operation in each band.

The DSA 2 concept is principally the same, however, with M6 separating X-and Ka-band and an additional dichroic M7 to separate Ka-band transmission and Ka-band reception. M8 is an elliptical mirror to minimize M6 and fit into the shroud dimensions. This is shown in fig. 5. H1 is the Ka-band Tx feed, H2 Ka-band Rx and H3 is the X-band feed.

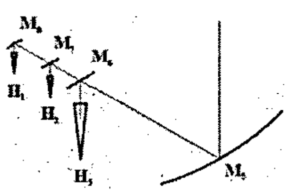

***Figure 5** - Mirror concept in antenna equipment room for DSA 2*

4.3 Dichroic Mirrors

The dichroic mirror M6 are different for DSA 1 and DSA 2 because of the different frequencies and are the most critical parts in the antenna. In both cases new development is necessary. The electrical requirements are summarized in the following Table 3.

Table 3 Dichroic frequency bands for DSA 1 and DSA 2

Parameter	DSA 1 (M6)	DSA 2 (M6)	DSA 2 (M7)	Dim.
Transmission bands	Tx: 7145 to 7235 Rx: 8400 to 8500	Tx: 34200 to 34700 Rx: 31800 to 32300	Tx: 34200 to 34700	MHz
Reflection Bands	Tx: 2025 to 2120 Rx: 2200 to 2300	Tx: 7145 to 7235 Rx: 8400 to 8500	Rx: 31800 to 32300	MHz

The design of these mirrors has to take into account the following parameters: Incident angle, Spillover Loss, I^2R Loss, Scatter Loss, Illumination, Cross-Polarization, Effects of Gravity Deformation, Beam Squint, PIM Noise.

Several mirror shapes were analyzed by calculating the performance impact. As the X-band receive performance was the most critical, it was used as main driver for the selection. Finally the Thick Cross / JPL Lattice Design was selected for DSA 1, which gave the performance impact as shown in Table 4. The JPL design is comparable to the thick cross Lattice design, however the JPL design could not be manufactured in the size required for the 35 meter ESA DSN antenna. Measurements of the real dichroic have validated the simulations.

The selection of the design for DSA 2 dichroic mirror is under investigation.

Table 4 Impact of M6 on Noise Temperature & Illumination Loss at 8.5 GHz (DSA 1)

Parameter	Thick Cross/ JPL Lattice Design	
	Loss (dB)	**Noise Temp**
Spillover, Scatter, I^2R	-0.170	11.2
4 Upper BWG Mirrors		1.5
Total		12.7
System Temperature		60.8
G/T Delta due to Ta	-0.220	
Illumination Loss	-0.286	

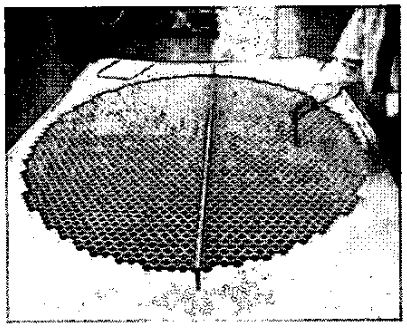

Figure 6 – Dichroic mirror at final mechanical testing

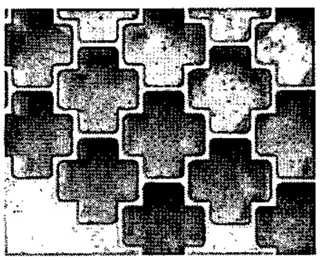

Figure 7 – Shape of holes and tolerance
Number of Cross holes: 2430
Accuracy: ± 50 μm
Thickness of mirror: 28 mm ± 0.1 mm

4.4 Low Noise amplifiers

The S-and X-band Low Noise amplifiers have been developed for this project and consists of cryogenically cooled HEMT amplifiers, that are housed in vacuum dewars and cooled down to 15 deg K in the inner stage.
A typical blockdiagram is shown in Fig.8.

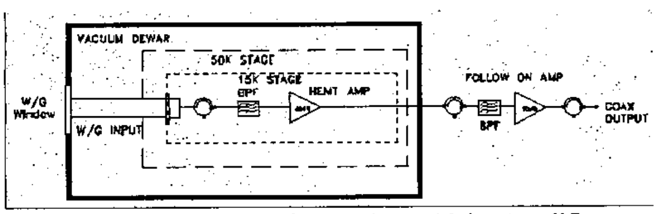

Figure 8 – Blockdiagram of S-Band Low Noise Amplifier

Each of the two S-band LNA chains comprise a cryogenic section, housed in a vacuum dewar, and an ambient temperature section. A Helium gas compressor provides compressed gas for the refrigerating the cold head in the dewar. Each Helium gas compressor is cooled using the circulated chilled water system.

The RF circuit comprises a wave guide vacuum window, an input wave guide assembly, a coaxial bandpass filter with input isolator, a cryogenic HEMT amplifier, a cryogenic rated output coaxial cable, an ambient temperature bandpass filter with input isolator and a post amplifier with output isolator.
The design performance of the S-and X-band LNAs is summarized in table 5 and has been generally met.

Table 5 LNA Performance

	Noise Temperature (K)	**Gain (dB)**	**VSWR**
S-band LNA	12.0	55.0	1.25:1
X-band LNA	18.5	55.0	1.25:1

4.5 The 20 KW High Power Amplifier

The antenna needs 20 kW transmitters in both S-and X-frequency bands. The HPA is cooled using high-pressure de-ionized chilled water. The 20 kW HPA consists of the following parts

- Low power RF section
- The microwave Klystron tube and high power RF section
- The high voltage power supply
- The mechanical packaging and cooling system
- The protection, monitor, and control system.

The low power section receives the RF signal from the upconverter. For major technical data see Table 6.

Table 6 HPA Performance

Parameter	**20 kW S-band**	**20 kW X-band**
Frequency range (MHz)	2025 – 2120	7145 – 7235
Bandwidth @ -1 dB	≥20 MHz	≥90 MHz
RF rated power level at HPA output waveguide flange, end of the useful life	≥20 kW	
Nominal gain	≥74 dB	≥75 dB
Automatic level control	Output level accurate to 0.5 dB peak-to-peak, when the input level varies by up to ± 3.0 dB from its nominal level	
Power consumption, maximum	<90 kW	
Cooling	De-ionised cooling water for Klystron	

4.6 Antenna Mechanical Structure and Antenna Building

The ESA DSA is comprised of main reflector supported and pointed by a pedestal comprised of the elevation and azimuth portions. The pedestal is mounted on the antenna building. (see fig. 9). The main reflector diameter is 35 meters and has the shape of a corrected paraboloid. The subreflector, approximately 4.3 meters in diameter is a shaped hyperboloid.

The azimuth housing is mounted on the antenna building by means of a single circular bearing and a fixed steel base ring. The bearing is of sufficient size to allow the BWG and a spiral access staircase pass through the centre from the antenna building to the azimuth housing.

The antenna building is a concrete and steel structure that supports the antenna pedestal and provides an environmentally controlled enclosure for the stationery elements of the BWG system, RF feeds, and electronic equipment.

The overall height of the antenna is around 40 meters and the total weight structure and equipment above the antenna building interface is approximately 620 tons. The weight of the main reflector is around 100 tons, the movable part of the elevation around 340 tons and the total movable part amounts to around 540 tons.

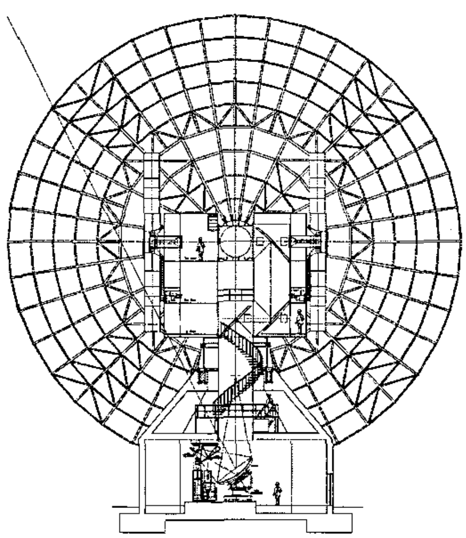

Figure 9 – Back-view of the antenna

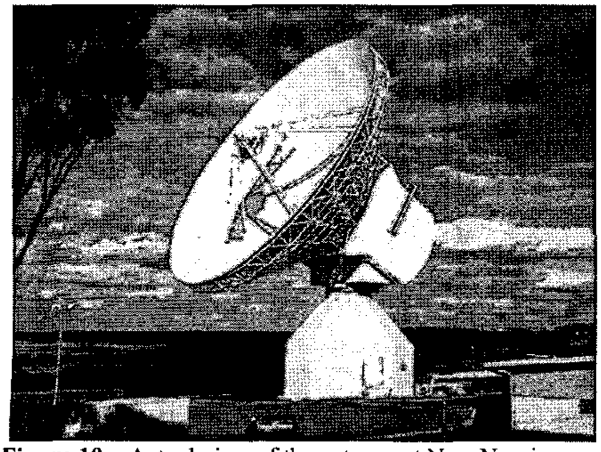

Figure 10 – Actual view of the antenna at New Norcia

4.7 Pointing Calibration System (PCS)

For DSA 1 a prototype of a pointing calibration system has been developed and has been used to validate the pointing accuracy of the antenna. DSA 2 will definitely need such equipment operationally to achieve the high pointing requirements for Ka-band.

Systematic effects (gravity deformations, misalignments, non-orthogonalities, RF beam squint, atmospheric refraction, constant wind, etc.) and random effects (encoder precision, motor cogging, wind gusts, etc.) lead to antenna pointing errors. The random contribution is approximately 50 % of the systematic pointing error contribution after the pointing calibration of the antenna and cannot be compensated. The systematic errors (without wind effects and atmospheric refraction) however can be modeled by mathematical functions (Pointing Error Model or PEM). The functions describe the behavior of the error component versus elevation and azimuth and they are weighted by coefficients, which have to be determined by radio star measurements.

Most of the systematic errors are purely mechanical frequency independant errors. The RF beam squint caused by the dichroic and the BWG depends on the used frequency band. The calibration process has therefore to be done at Ka-band using radio stars transmitting at this frequency band. Due to the very low radio star flux at Ka-band a Noise-Injection Radiometer (NIR) is used. This allows an integration time of several seconds at each measurement point without deteriorating the accuracy due to variations in the front-end.

The PCS determines the antenna pointing offsets by pointing the antenna to the expected position of the radio star and by scanning around this expected position. Such measurements are done with different radio stars and at different times to cover the full hemisphere. The result of these measurements is used to determine the coefficients of the PEM, minimizing the remaining pointing error.

Besides the purely systematic errors, wind and thermal effects have a major impact on the antenna pointing. The wind is partially compensated by a specific wind optimized controller for the antenna drives. Measuring the tilting of the azimuth housing caused by thermal gradients and the temperature of the structure will be used to reduce the thermal impact on the pointing.
The ray bending through the atmosphere (refraction) is very large at low elevation angles. Depending on ambient conditions, this refraction error can reach several tenth of a degree and has therefore to be compensated. The atmospheric refraction is modeled by an analytical function

derived from a ray-tracing model using the ambient temperature, air pressure and humidity as parameters. These data are obtained from a weather station on-site, close to the 35m antenna.

During normal antenna operation, the compensation of the systematic pointing errors is done within the antenna control unit (ACU) by applying offsets to the elevation and azimuth positions. The offsets are determined from the PEM, the tiltmeters, the thermal distortion model and the atmospheric refraction model. The PCS will also be used for a regular verification of the pointing of DSA 2.

5. ESA DEEP SPACE NETWORK

The Inter-Agency Consultative Group for Space Science (IACG), comprising members from NASA, ESA, ISAS and RASA have surveyed their respective future plans for deep space missions (in particular to Mars) since there appeared to be an increasing load on and demand for ground tracking and data acquisition facilities. The possibility for cross-support capabilities were analyzed on the basis of a joint mission model and existing / firmly planned ground tracking facilities. It was determined that only a few non-NASA/DSN tracking sites have large dishes (34m/70m class) and most utilize wrong frequencies, i.e. not in the required deep space S-Band, X-Band or Ka-Band. Where the capability is commensurate with deep space cross-support requirements, the respective agencies missions occupy the antenna prime subscription. Therefore these stations can only be considered for the potential provision of limited back-up and/or emergency support for telemetry reception.

Taking note of the above ESA has determined that it is necessary to have its first 35m DSA at New Norcia amended by a second deep space ground station as part of its infrastructure to maintain the support capability to its present and future missions. As such the second deep space ground station will be used as a multi project facility concurrently with missions from the Science Directorate. This will provide a further step towards a European Deep Space Network, as scoped by the Network of Centres initiative, whereby initializing the use of Ka-Band technologies and constituting a nucleus for the Aurora program anticipated by the Agency.

In view of complementing the visibility/coverage provided by the New Norcia station, the required radio frequency clearance for data transmission and reception, the weather conditions influencing station performance (rain attenuation, wind speed), and the need for cost efficient operations and maintenance it was decided to install the second deep space antenna front-end at Cebreros (Spain).

The design and development of ESA's first and second deep space ground station has been made such to be fully compatible with the CCSDS Space Link Extension (SLE) Services, which defines standards for telemetry, telecommand and radiometric data exchange. Thus, it is ensured that the ESA station(s) are fully compatible with e.g. the NASA Deep Space Network (DSN) ground stations, which follow the same standards, whereby allowing efficient and quick implementation of cross-support.

ESA and NASA have recognized the value in having the technical capability for "bi-directional" interoperability between their respective deep space tracking assets (i.e. to track NASA spacecraft at ESA deep space tracking sites, and to track ESA spacecraft at the NASA deep space tracking sites). Bi-directional interoperability will have the following mission risk-reducing benefits: (1) ability to provide mission critical support in the event of non-availability of the prime tracking station due to reasons such as local weather interference; (2) ability to back up a local ground station in case of a failure during a mission critical event; (3) ability to fill in what would otherwise be "missed coverage" during planned station down times; and (4) ability to alleviate tracking network over-capacity and over-demand.

Investigations are about to start to analyze the need and possibility augmenting the New Norcia and Cebreros deep space stations by a third one.

6. CONCLUSION

The development and installation of the ESA 35m deep space antenna at New Norcia constituted a major technical and programmatic challenge. In particular the dichroic mirror design and manufacturing, the cryogenically cooled HEMT low noise amplifiers and the 20 kW High Power Amplifiers, as well as the 540 tons mechanical structure required high technical solutions to meet the stringent performance requirements, imposed by the deep space missions. In June 2002 the antenna successfully tracked its first spacecraft, STARDUST at a distance of 300 million km from earth.

In July the overall performance was validated and the specifications were reached to cope with the requirements and the future mission needs. Subsequently, the operational readiness was proven with the Ulysses and Cassini spacecraft revealing excellent tracking, command and data acquisition capabilities. Since June 2003 the antenna is successfully used with daily contacts to Mars Express demonstrating its capability to support a wide range of future deep space missions. The second deep space antenna as contracted, is principally of very similar design, however will need a number modifications because of different frequencies and more stringent requirements.

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8 BIBLIOGRAPHY

Rolf Martin *(graduated Communication engineer) is staff of the European Space Agency (ESA) and is head of the antenna and infrastructure section. Before he was 20 years in german space industry (MBB, now Astrium) and has developed, managed and implemented all antennas of the ESA Estrack network. He was the Technical Officer for the first European Deep Space Antenna at New Norcia/WA, as described in this article, and is also responsible for the second one, being currently under construction in Spain.*

Dr. Manfred Warhaut *(PhD in Physics) worked at Max Planck Institute (MPI) Heidelberg in the area of cosmophysics. From 1979 to 1986 at German Space Agency (DLR) Cologne, Spacecraft Transportation System (STS) Manager in the German Spacelab D-1 Mission. As of 1987 with ESA/ESOC, initially Study Manager for several science projects and subsequently Ground Segment Manager for the Cluster and Cluster II missions. At present Ground Segment Manager for Rosetta and Venus Express and Project Manager for ESA's Deep Space Ground Stations.*