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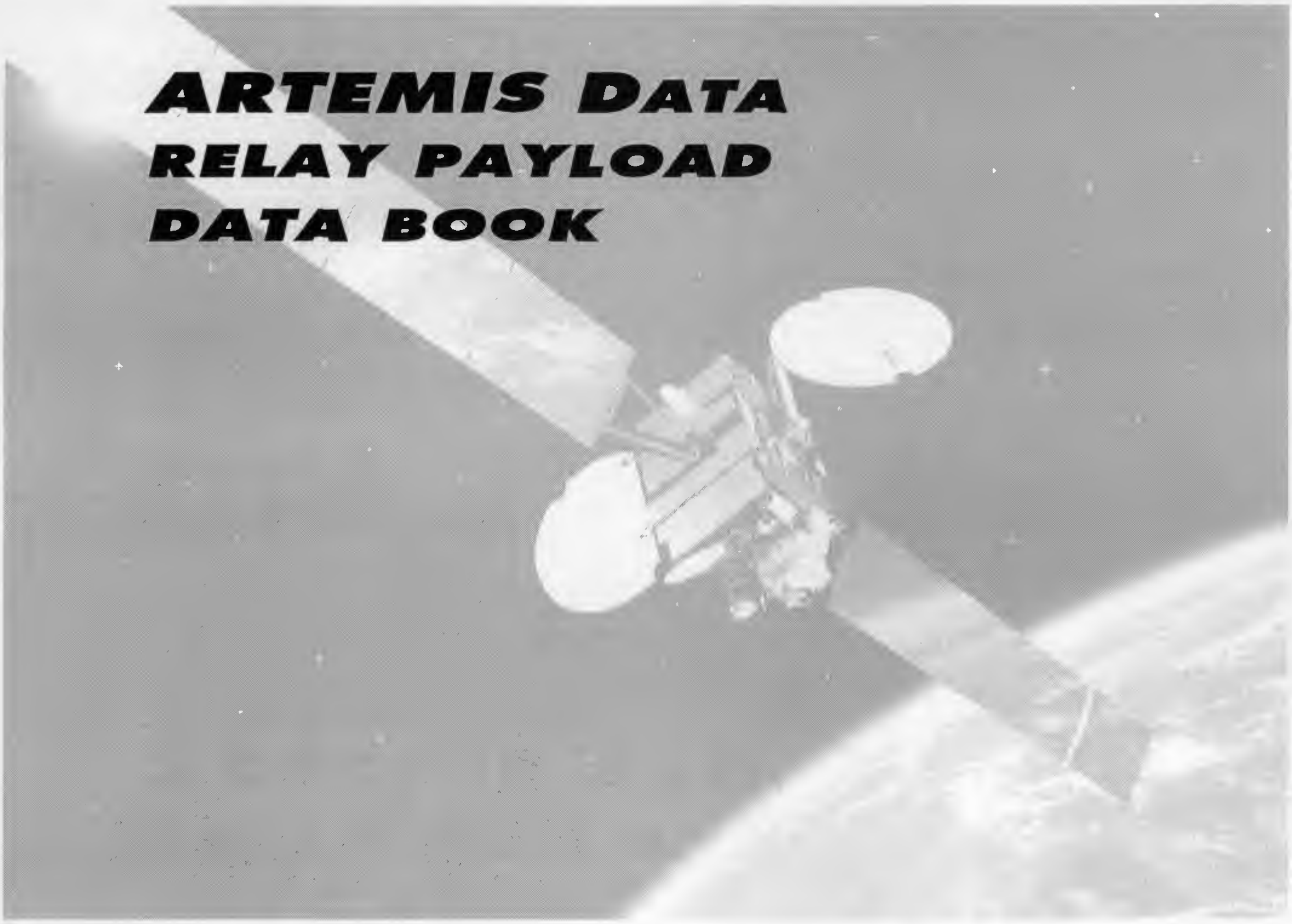

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European Space Agency
Agence spatiale européenne

Station Redu - Redu Station
6890 Redu, Belgique
Tel. (32) 61 229511 - Fax (32) 61 229544

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TABLE OF CONTENTS

LIST OF ABREVIATIONS

ALC	Automatic Level Control
APS	Antenna Pointing System
ARTEMIS	Advanced Relay and TEchnology MIssion Satellite
BOL	Beginning Of Life
BPSK	Binary Phase Shift Keying
DRS	Data Relay System
EIRP	Equivalent Isotropic Radiated Power
ESA	European Space Agency
EOL	End Of Life
FBOF	Forward 23 GHz Beacon Output Filter
FICA	Forward Intermediate Frequency Amplifier
FIKC	Forward 5.5 / 23 GHz Ka-band Converter
FIKF	Forward 5.5 GHz Ka-band Channel Filter
FISC	Forward 5.5 / 2 GHz Converter
FISF	Forward 5.5 GHz S-band Channel Filter
FKIC	Forward 30/5.5 GHz Converter
FKIF	Forward 30 GHz Input Filter
FKLA	Forward 30 GHz Low Noise Amplifier
FKOF	Forward 23 GHz Output Filter
FKPA	Forward K-band TWT Power Amplifier
FODM	Forward 5.5 GHz / ODR Demodulator
FRGU	Frequency Generator Unit
FSPA	Forward S-band SSPA
GEO	Geostationary Earth Orbiting
IOL	Inter Orbit Link
IOLA	Inter Orbit Link Antenna
IOT	In Orbit Testing
KANA	Ka band Antenna
KBEA	Forward 23 GHz Beacon Antenna
LEO	Low Earth Orbiting
ODR	Optical Data Relay
ORH	Operational Requirements Handbook
PFD	Power Flux Density
QPSK	Quadrature Phase Shift Keying
RICA	Return 5.5 GHz Channel Amplifier
RIKC	Return 5.5 / 20 GHz Frequency Converter
RINF	5.5 GHz Narrowband Filter
RISF	5.5 GHz Channel Filter
RIWF	5.5 GHz Wideband Filter
RKIC	Return 26/5.5 GHz Frequency Converter
RKIF	26 GHz Input Filter
RKLA	Return Ka band Low noise Amplifier
RKOM	Return 20 GHz Output Multiplexer
RKPA	Return Ka-band TWTA
RKSF	Return 26/5.5 GHz Frequency Filter
ROMD	Return 5.5 GHz Optical BPSK Modulator
RSIR	Return 2/5.5 GHz Receiver
SKDR	S and K band Data Relay
SSPA	Solid State Power Amplifier
TWT	Travelling Wave Tube

UET	User Earth Terminal
UST	User Space Terminal

1 INTRODUCTION

1.1 Purpose of the document

This document is intended as a guide to the user community wishing to avail themselves of the services provided by the data relay system, which is based on the ARTEMIS satellite located over Europe. This document describes the services that data relay can offer and the interface requirements applicable to the UST and the UET.

1.2 Applicable documents

[AD1]	Advanced Relay and Technology Mission (ARTEMIS), Satellite Performance Specification, SP-8-1-1, issue 9, January 1998
[AD2]	SKDR payload ORH, ORH/SKDR/040-92/SE issue 7, 21/05/1998
[AD3]	ARTEMIS Data Relay Payload IOT results as measured from Redu in Feb/Mar 2003, DTOS-REDU-IOT-TR-3018-OR, issue 1, 28 May 2003
[AD4]	ESA Data Relay System Characteristics for users. DRTM programme Office, CD/201/AD/mad issue 6 December 1996.
[AD5]	SNIP S-band communications Services and Requirements for Interoperability June 10, 1994

2 DESCRIPTION OF THE DATA RELAY SYSTEM

2.1 General

The Advanced Relay and Technology Mission (ARTEMIS) satellite is part of the Data Relay and Technology Mission programme (DRTM).
ARTEMIS is a communication technology demonstration satellite, for data relay, navigation and land mobile applications.
The baseline payloads are:

- An S-band (2.0/2.2 GHz) data relay payload (SDR) to provide a data relay service for low to medium data rates to Low Earth Orbit (LEO) spacecraft;
- A K-band (23/26 GHz) data relay payload (KDR) to provide a data relay service for medium to high data rates to LEO spacecraft;
- A laser optical data relay communication experiment (ODR), providing a high data rate link with a LEO spacecraft. This system is known under the name SILEX;
- An L-band (1.5/1.6 GHz) land mobile services payload (LLM) providing spot beams and exercising frequency re-use;
- A navigation payload to become part of the global navigation satellite system (EGNOS – European Global Navigation Overlay System);
- A number of spacecraft technology advances, such as ion propulsion and Nickel-Hydrogen batteries, improving platform capability;

- Experiments to monitor critical payload interfaces and platform environment: micro-vibrations monitoring, ion propulsion diagnostic package, and optical payload mission telemetry.

The above payloads are capable to operate simultaneously.
All the payloads were tested from ESA-Redu station during the IOT campaign, in February and March 2003.

The Data Relay System is aimed at providing advantages to Users in the following areas:

- A significant increase in coverage area over that provided by existing conventional earth station networks;
- A reduction or virtual elimination of the need for onboard data storage;
- A reduction or virtual elimination of any time delay between the transmission of the data from the User spacecraft and their reception by the end Users on the ground;
- A minimisation of secondary data distribution problems on the ground;
- An increased flexibility in scheduling operations for Users.

The basic objective of the overall Data Relay System programme is to set-up a system, in space and on the ground, in support of the space programmes, which will provide the following quasi continuous services:

1. Communication Service:

   - Relay of experimental / scientific data from Low Earth Orbiting Spacecraft to the ground station;
   - Relay of video and voice between manned or unmanned Low Earth Orbiting Spacecraft and User Spacecraft Control Centres;
   - Relay of telemetry and telecommand between User Spacecraft Control Centres and User Spacecraft in Low Earth Orbit;

2. Localisation Service:

   - The capability to carry out ranging operations for orbit determination of User Spacecraft.

To meet these objectives, the principal elements of the Data Relay System (DRS) are:

- The DRS Satellite (DRSS) called ARTEMIS (Advanced Relay TEchnology MISsion), in geostationary Earth Orbit (GEO) so as to provide wide coverage for relay of data and ranging signals between Earth Terminals in Europe and the User Spacecraft over as much of their orbits as possible.
- The DRS Management Facilities, operated by ESA, that manage both the setting up and the maintenance of the telecommunication links.
- The DRS also provides facilities for In-Orbit Testing of the Data Relay System, as well as the facilities to enable User Spacecraft to be tested prior to launch through the DRS.

2.2 Link definitions

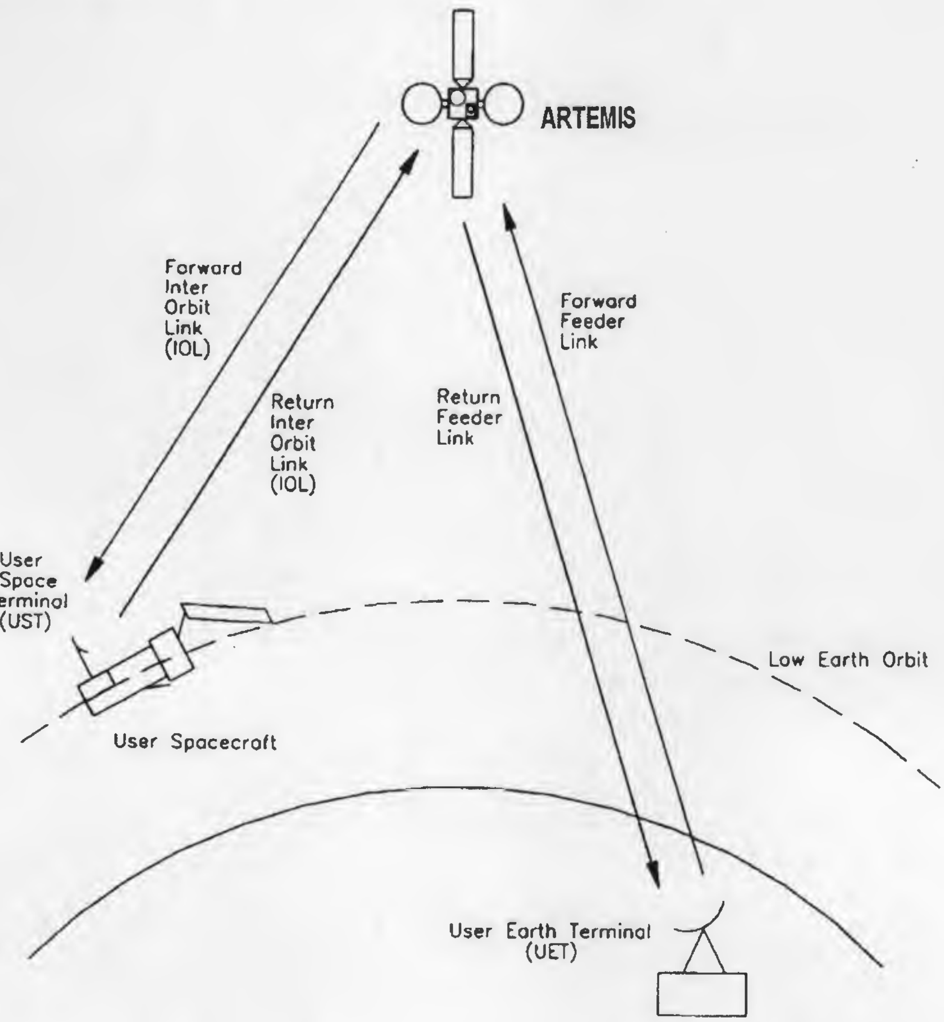


Figure 1 Overall DRS links

The purpose of the Data Relay System is to provide telecommunication and localisation services to the User systems, where the User systems include:

- User Space Terminal (UST), comprising the receivers, transmitters and antennas mounted on the User Spacecraft in Low Earth Orbit (LEO), nominally up to 1000 km of altitude.
- User Earth Terminal (UET), which receives data from the User Spacecraft via the DRS satellite and may also transmit data and commands to the User spacecraft via the DRS satellite.

The communication links consist of two parts: the Feeder Links between the Earth Terminals and DRSS and the Inter-Orbit Link (IOL) between the DRSS and the UST. Links in the direction Earth

– DRSS – UST are called Forward Links and links in the direction UST-DRSS-Earth are called Return Links. These links are shown schematically on figure 1.

The frequency bands used via the DRS are the following:

Forward Links

- Feeder Link: 28.5 to 30.0 GHz
- Inter Orbit Link: 2.025 to 2.110 GHz
  23.12 to 23.55 GHz
  820 nm (optical)

Return Links

- Inter Orbit Link: 2.200 to 2.290 GHz
  25.25 to 27.50 GHz
  848 nm (optical)
- Feeder Link: 18.10 to 20.20 GHz

2.3 *Orbital position*

ARTEMIS position is 21.45° E, with an inclined orbit of 2° at the time of writing.
To counter the orbit inclination effects on the earth coverage zone, a pitch, roll and yaw correction mechanism has been implemented. This implementation was validated during the IOT campaign. The following figure depicts the evolution of the inclination with respect to the elapsed operation time.

Figure 2 ARTEMIS inclination evolution over time

2.4 DRS coverage

The ARTEMIS orbital position is 21.45 degrees East which is fairly well centred above Europe and hence an optimum position for the Feeder Link. The coverage of the User Spacecraft for the ARTEMIS position is shown in figure 3.
The feeder link coverage of Europe is schematically shown in figure 4, more detailed maps are given in Appendix B and C.

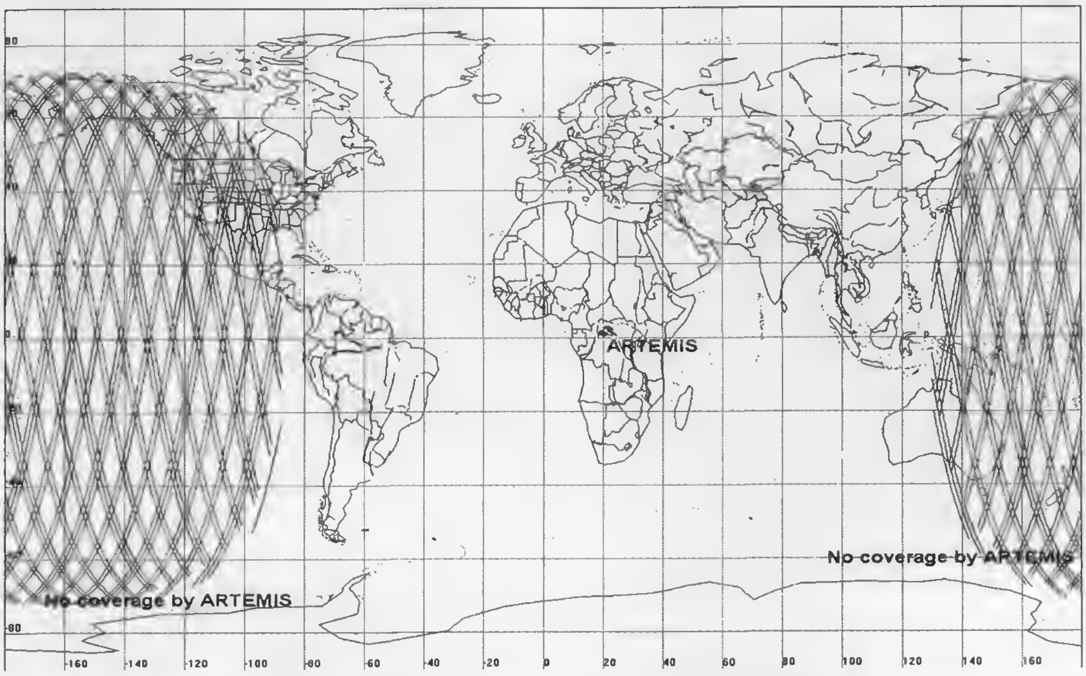


Figure 3 User Spacecraft coverage for ARTEMIS

Figure 4 European Feeder Link Coverage

Whilst figures 3 and 4 show the User Spacecraft coverage, taking into account the occultation due to the earth, other factors influence the actual duration of the communication offered by the DRS to the Users. The DRS non-availability may be caused by :

1. Earth occultation
2. User Spacecraft body and appendages occultation
3. UST antenna azimuth and elevation limitations
4. UST antenna dynamic limitations
5. Sun blinding
6. UST acquisition time

Causes 2, 3, 4 and 6 depend on the actual User Spacecraft geometry and attitude and the relevant effects vary on a case by case basis. Therefore for each User Spacecraft, the link occultation has to be determined on the basis of specific characteristics of the User Spacecraft and the UST.

Causes 1 and 5 are predictable and depend on the User Spacecraft to DRSS link geometry. Sun blinding can produce occultation of the Forward Link (Sun in the UST antenna beam) or of the Return Link (Sun in the DRSS IOL antenna beam) due to an increase in Front End system noise temperature.

Finally, Power Flux Density (PFD) constraints on Earth must be respected by both the DRSS and the UST transmissions. To cope with such a regulation:

- A tight EIRP control is needed on DRSS.
- A silent period may have to be imposed on the User Spacecraft when the Earth is within the antenna beam.

The factors affecting the coverage between User Spacecraft and DRSS are also discussed in Appendix B.

2.5 *System capacity*

2.5.1 GENERAL

This section describes the total capacity of the Data Relay System. Individual Users will be allocated part of this total capacity.

2.5.2 NUMBER OF IOL ACCESSES AND CHANNELS

ARTEMIS is providing up to 2 simultaneous forward accesses, namely:

- 1 Forward 23 GHz or 2 GHz access
- 1 Forward Optical access

In the return direction, provision is made to support up to 4 simultaneous channels amongst :

- 3 return 26 GHz channels.
- 1 return Optical channel.
- 1 return 2 GHz channel.

The maximum number of simultaneous channels should not exceed 4 and in case of a simultaneous usage of the S and Ka bands, the user must be the same, as the same steerable IOL antenna is used for both systems.

2.6 Frequency plan and utilisation

2.6.1 GENERAL

The DRS is highly flexible such that it is simple for the Users to interface with the system. This is achieved by the following characteristics:

Return Link

- Fixed IOL frequencies is assigned to each UST.
- It is possible to support User Spacecraft with up to 3 return channels on Ka-band return.
- The UET, however, shall be capable to receive the return signal at any of the return feeder link channel frequencies.

Forward Link

- It is possible to assign to each critical mission a dedicated forward feeder link frequency that is not to be used by any other mission. This is done to prevent ground stations from blocking the forward channel to a User Spacecraft by inadvertently switching on or not switching off its transmitter. Therefore, there are more installed forward feeder link channels on DRSS than the maximum that can be operated simultaneously.

2.6.2 FREQUENCY PLANS

This section provides the DRS communication carrier frequencies. Specific Users, however, have to notify their transmit frequency via the normal procedures and should seek advice from the DRTM Programme Office regarding the most suitable carrier frequency from an interference point of view.

2.6.2.1 Frequency plan for the Forward Link

The frequency band for the forward feeder link is from 28.50 to 30.00 GHz. The frequency plan is shown in figure 5.

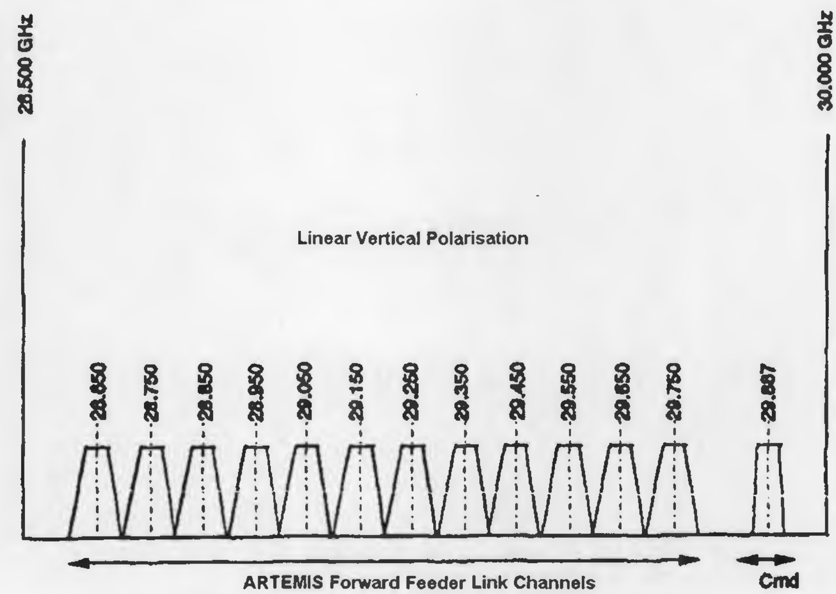


Figure 5 Forward Feeder link frequency plan

For the forward IOL in 2 GHz band, it is possible for DRSS to transmit at any frequency from 2.025 to 2.110 GHz and the channel is selectable by 0.5 MHz steps.

For the forward IOL in 23 GHz band, the frequency plan is shown in figure 6.

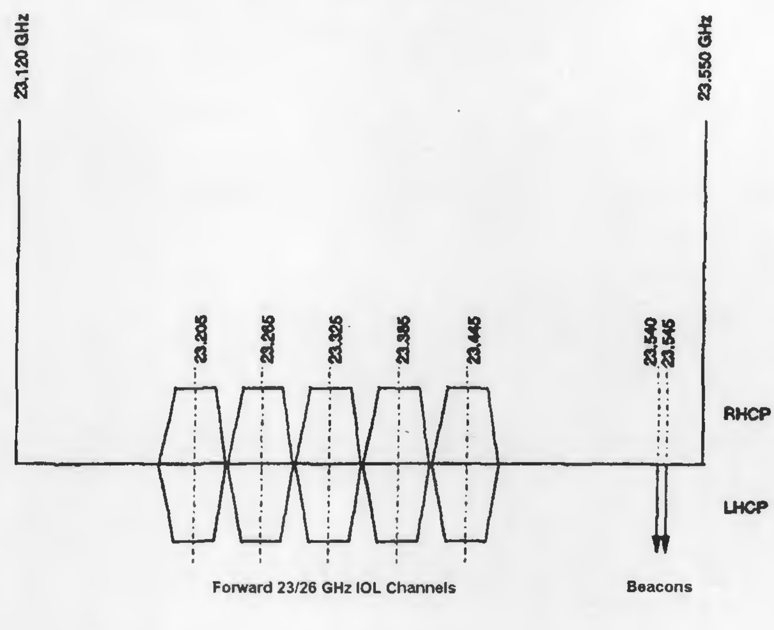


Figure 6 Forward IOL frequency plan

For the forward IOL of the Optical payload, the wavelength is 820 nm.

2.6.2.2 Frequency plan for the Return Link

For the return IOL in 2 GHz band, it is possible for the DRSS payload to receive at any frequency from 2.200 to 2.290 GHz in steps of 0.5 MHz.

For the return IOL in 26 GHz band, the frequency plan is shown in figure 7.

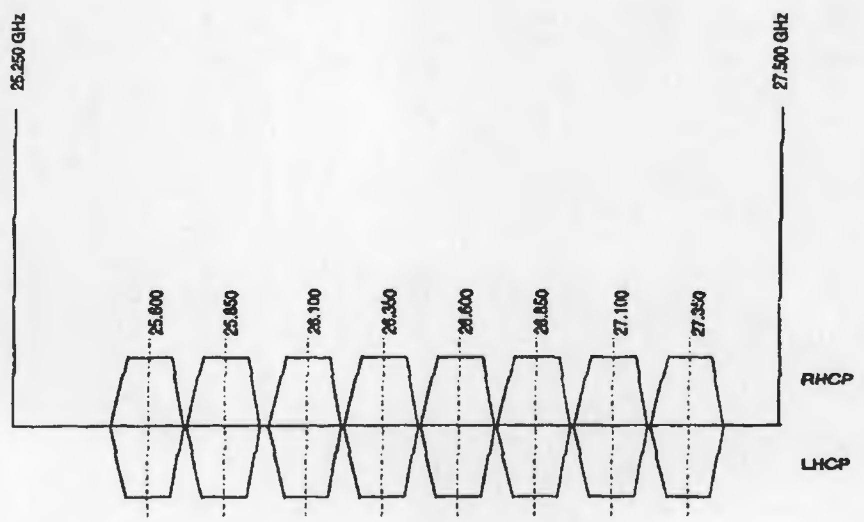


Figure 7 Return 26 GHz IOL frequency plan

For the return IOL of the Optical payload, the wavelength is 848 nm.

The frequency band of the return feeder link is from 18.1 to 20.2 GHz. The frequency plan is shown in figure 8.

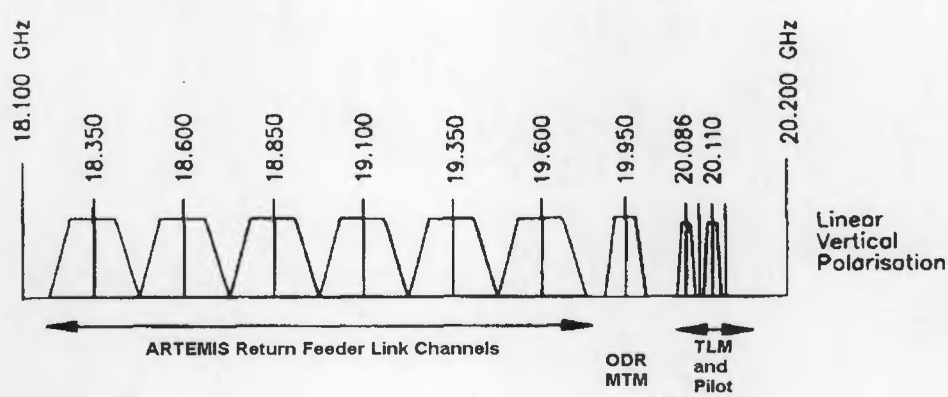
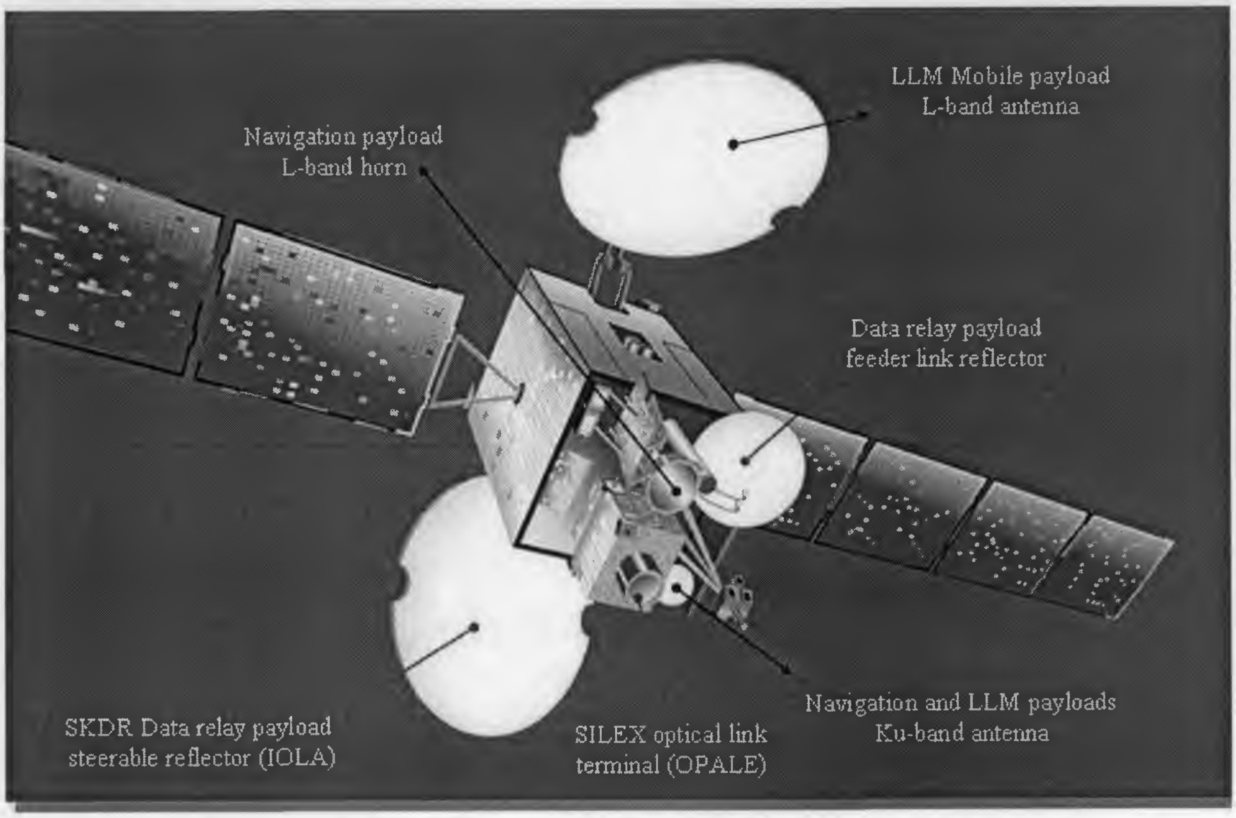


Figure 8 Return Feeder Link Frequency plan

3 PAYLOAD DESCRIPTION

The payload block diagram is depicted in A-1

The following picture shows the different antennae and their positions.



Satellite characteristics	
Mass at launch	3,100 kg
Power consumption	2.5 kW
Height	4.8 metres
Length	25 metres (solar array tip to tip)
Width	8.0 metres (with antennas deployed)
Launch	2001
Lifetime	10 years
Orbital position	21.45°E

3.1 *Ka-band Antenna (KANA)*

The European coverage antenna uses a single shaped reflector which is illuminated by two independent feeds procuring two contoured beams over Europe as seen from 59 °E and 21.45 °E orbital positions. These two feeds are switched in flight depending on the satellite orbital position, so that only one of the feeds is active.
The antenna is fixed and mounted on the satellite body, Earth face panel, without any re-pointing mechanism after launch.
The antenna is used simultaneously for transmitting and receiving beams.
Transmit and receive patterns are shown in annexes B and C.
Figure 9 depicts the outline of the antenna assembly and the block diagram is shown in figure 10.

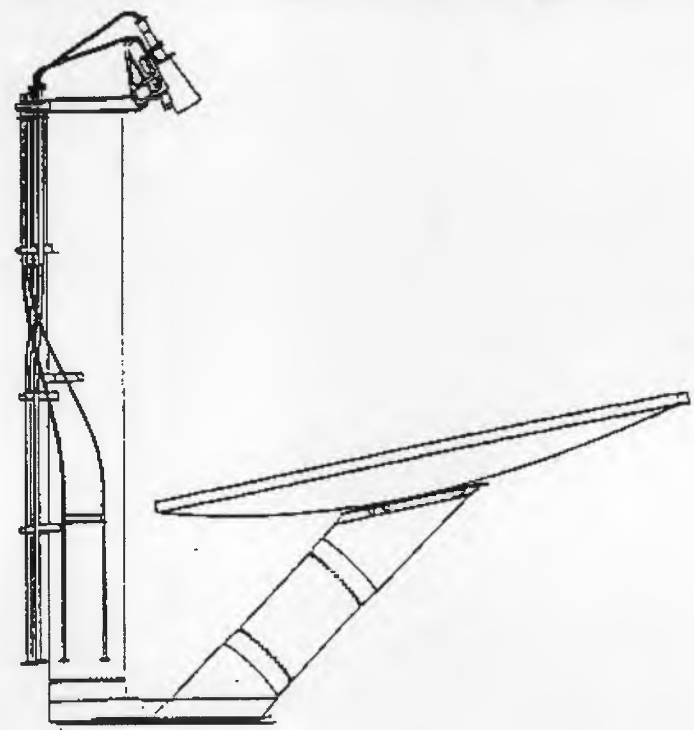


Figure 9 KANA outline

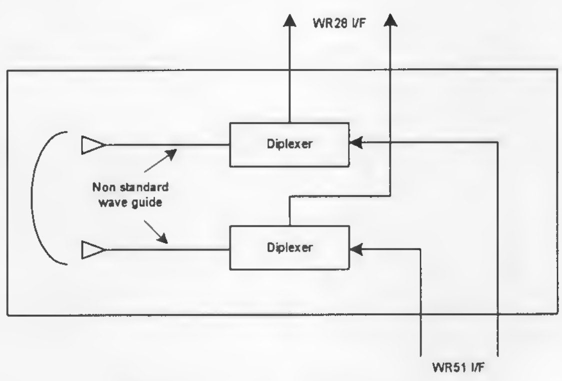


Figure 10 KANA block diagram

3.2 *Forward 30 GHz Input Filter (FKIF)*

The unit is a 30 GHz Input Filter operating on the 28.625 – 29.890 GHz frequency range. It is connected to the RX antenna and to the 30 GHz Low Noise Amplifier by transfer switches (FKIS 1 & 2). The FKIF design is a 7 poles band pass filter with Tchebyshev response.
Wave guide technology is used.

3.3 *Forward 30 GHz Low Noise Amplifier (FKLA)*

The equipment is a 30 GHz HEMT Low Noise Amplifier providing very low noise figure, high gain and active compensation of temperature effects. The forward 30 GHz LNA consists of two electrically independent LNA's (each of them being provided with its own DC/DC converter) combined at RF output by two 3dB output couplers to provide redundancy.

3.4 *Forward 30/5.5 GHz Converter (FKIC)*

The equipment is used to convert one of the multiple received 30 GHz RF channels to a fixed IF output of 5.5 GHz.
This unit consists of:

- A mixer with a LO signal derived from the LO synthesizer through a frequency doubler.
- A tunable LO that generates the mixer LO signal adjustable by telecommand in steps of 50 MHz before the frequency doubler. The forward channel is thus adjustable by steps of 100 MHz.
- A wideband 5.5 GHz amplifier.
- A DC/DC converter to supply the sub-units with a stabilized voltage

A Ka-band low pass wave guide filter has been inserted at the FKIC-1 in order to filter the 2xLO converters input spurious.
This filter cut-off frequency is 31 GHz and no tuning is available.
Both units can be used simultaneously.

3.5 *Forward Intermediate Frequency Amplifier (FICA)*

The equipment is a 5.5 GHz Automatic Level Control (ALC) Channel Amplifier, allowing output level setting in discrete steps (64) controlled by ground telecommand and providing active compensation of temperature effects.
The schematic block diagram is shown in figure 11.
The main characteristics are:

- Channel center frequency f0: 5.5 GHz
- O/P power settable in the range –37 to -3 dBm by steps of less than 1 dB
- Gain variation w.r.t. frequency: 0.3 dBpp over f0 +/- 19 MHz

One redundant unit is provided.

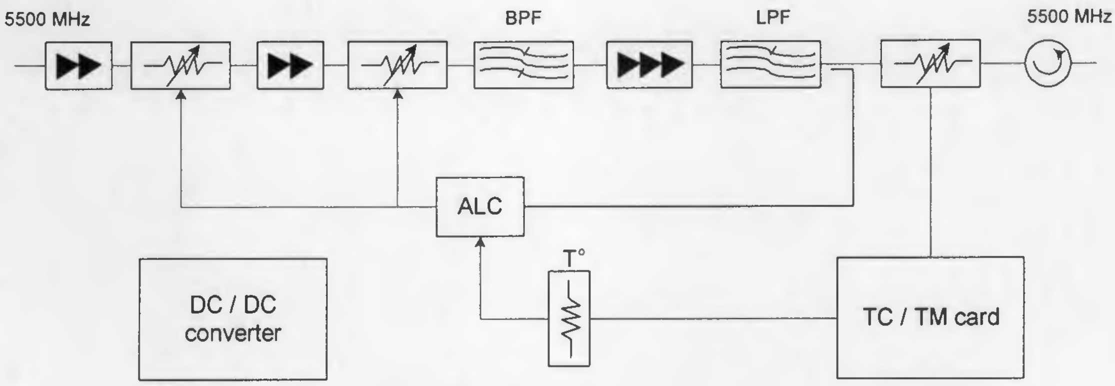


Figure 11 FICA block diagram

3.6 *Forward 5.5 GHz ODR Demodulator (FODM)*

The 5.5 GHz ODR demodulator is a BPSK demodulator working on an input signal BPSK modulated by a differential encoded NRZ data stream at 2048 kbps.
The equipment performs the following functions:

- Clock synchronization
- Differential decoding
- BPPM data encoding

Data signal characteristics:

- Data rate: 2048 kbps
- Duty cycle: 50% +/- 5%
- Phase jitter: +/- 5% max
- Transition time (20 to 80%) 1 ns max
- Output voltage: ECL

No redundancy is provided.

3.7 *Forward 5.5 GHz Ka-band Channel Filter (FIKF)*

The 5.5 GHz IF channel filter is located at the output of each converter (FKIC) to prevent spurious transmission in the receiving bands (L-band, S-band and Ku-band). A third filter is also inserted between the FICA output and the Ka-band converter input.
The units, externally equalized consist of:

- Low pass filter
- Channel filter
- Isolator
- Group delay circulator
- Group delay equalizer

The schematic block diagram is depicted in figure 12.

The main characteristics are the following:

- Nominal center frequency : 5.5 GHz
- Channel bandwidth: 38 MHz

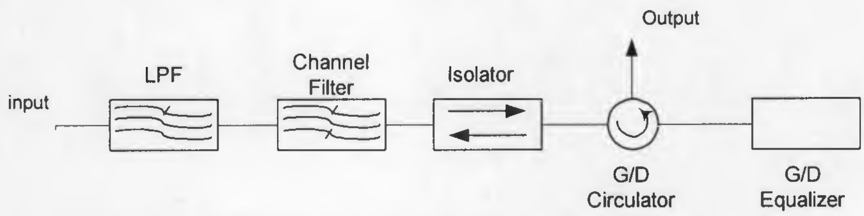


Figure 12 FIKF and FISF block diagram

3.8 *Forward 5.5 GHz S-band Channel Filter (FISF)*

The 5.5 GHz channel filter is located at the FICA output.
The units, externally equalized consist of:

- Low pass filter
- Channel filter
- Isolator
- Group delay circulator
- Group delay equalizer

The schematic block diagram is depicted in figure 12.

The main characteristics are the following:

- Nominal center frequency : 5.5 GHz
- Channel bandwidth: 8.8 MHz

3.9 *Forward 5.5 / 2.0 GHz Converter (FISC)*

The unit is used to convert the input signal, in the frequency band of 5.5 GHz, to a selectable channel output frequency in the 2.0 GHz band.
The equipment is a tunable frequency down-converter providing a 5.5 GHz automatic level controlled channel amplification with a fixed output level.
Redundancy 1 / 2 is provided.

The equipment consists of:

- A 5.5 GHz amplifier
- A mixer module

- A telecommandable local oscillator adjustable in steps of 0.5 MHz in the range 3390 MHz to 3475 MHz.
- A wideband output amplifier
- A DC/DC converter that supplies the unit with a well regulated voltage.

The main characteristics are:

- Input channel center frequency: 5500 MHz
- Output channel center frequency: 2025 – 2110 MHz (by steps of 0.5 MHz)
- Gain vs. frequency: over operating BW 0.5 dBpp.

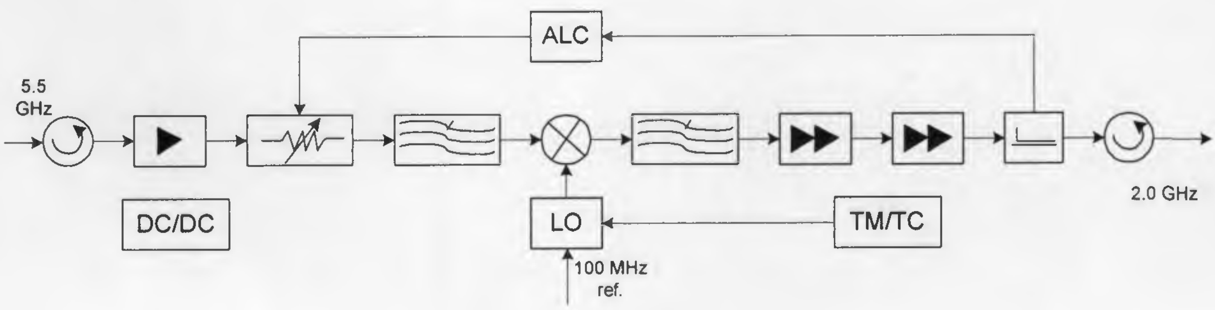


Figure 13 FISC block diagram

3.10 *Forward 5.5/23 GHz Ka-band Converter (FIKC)*

The equipment provides single step frequency conversion of one channel from a fixed 5.5 GHz frequency to a selectable channel output frequency in the 23 GHz band. Three converters are used to process the communication channel and the beacon signal. All the converters can process the communication signal while only two can be dedicated to the beacon signal.
Each unit consists of:

- A mixer with a LO signal derived from the LO synthesizer through a frequency doubler.
- A tunable LO that generates the mixer LO signal adjustable by steps of 2.5 MHz in the range 8852.5 MHz to 9022.5 MHz.
- A DC/DC converter that supplies the required regulated voltages.

The main characteristics are:

- Input channel center frequency: 5500 MHz
- Output channel center frequency:
    - Channel A1 23205 MHz
    - Channel A2 23265 MHz
    - Channel A3 23325 MHz
    - Channel A4 23385 MHz
    - Channel A5 23445 MHz
    - Channel A6 23505 MHz
    - Beacon 1 23540 MHz generated by beacon FRGU

- Beacon 2 23545 MHz generated by beacon FRGU

- Channel bandwidth: 45 MHz
- Gain vs. frequency: over the channel BW 0.31 dBpp
- Redundancy scheme: 2 / 3

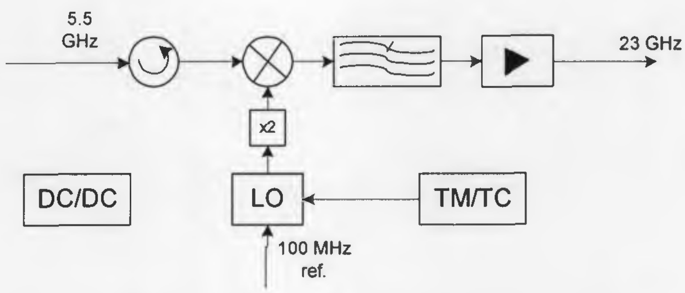


Figure 14 FIKC block diagram

3.11 *Forward S-band SSPA (FSPA)*

The 2.1 GHz 30W solid state power amplifier for the SDR package, is a high power amplifier allowing output level setting in discrete steps controlled by external telecommands.
Performance characteristics:

- Operating frequency range: 2025 – 2110 GHz
- RF rated Output power: 45.2 dBm
- Output power control range: 0 to 25 dB
- Output power control step: 1 dB
- Output power stability: 0.15 dBpp vs. any 10K temp variation
- Redundancy scheme: 1 / 2

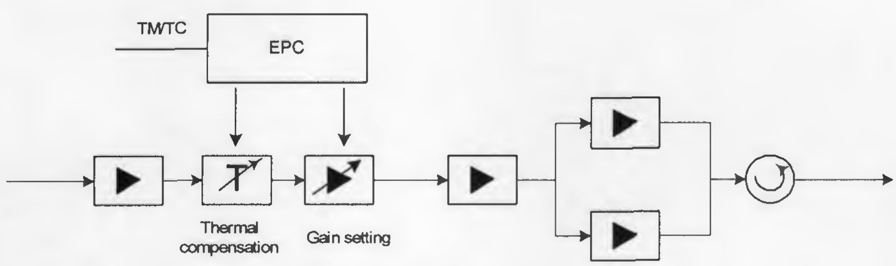


Figure 15 FSPA block diagram

3.12 *Forward K-band TWT Power Amplifier (FKPA)*

The 23 GHz 35 W Travelling Wave Tube Amplifier for the KDR payload consists of a TWT and an Electronic Power Conditioner (EPC) which generates the stabilized voltages required for operating the TWT.

Performance Characteristics:

- Operating frequency range: 23.12 – 23.55 GHz
- Gain with single carrier at sat: 55-60 dB
- Output power at sat: 35.5 – 37 dBW BOL, 35 dBW EOL
- Redundancy scheme: 2 / 3

3.13 Forward 23 GHz Beacon Output Filter (FBOF)

The unit is an output filter operating on the 23 GHz frequency band. It consists of one band pass filter and one low pass filter. The band pass filter (6 poles, pseudo-elliptic, cylindrical dual-mode cavities) assures the near out-of-band rejection and the low pass filter (11poles, Tchebyshev, corrugated wave guide technology) assures the far out-of-band rejection.
It is connected to the beacon antenna (KBEA).

Performance characteristics:

- Useful bandwidth: 23.539 – 23.546 GHz
- Out-of-band rejection:
  - 23600 – 24000 MHz: > 26 dB
  - 25250 – 27500 MHz: > 58 dB
  - 28500 – 30000 MHz: > 80 dB

3.14 Forward 23 GHz Beacon Antenna (KBEA)

The Ka-band beacon configuration consists of:

- A double orthomode transducer (OMT) from standard WR42 wave guide to circular wave guide.
- A three irises polarizer in circular wave guide.
- A mode exciting section.
- A longitudinally profiled horn.
- A support bracket including attachment I/F flange.

The antenna operates in left hand circular polarization (LHCP), with a minimum gain of 15 dBi and a polarization purity of more than 20 dB within a 20.5 degrees earth coverage cone.

3.15 Forward 23 GHz Output Filter (FKOF)

The unit is an output filter operating on the 23 GHz frequency range. It consists of a 9 poles variable width rectangular cavities inductive band pass filter.
This unit is connected through the transfer switch to the IOL antenna.

Performance characteristics:

- Useful bandwidth: 23185 – 23465 MHz
- Out-of-band rejection:
  - 18005 – 20100 MHz: 73.3 dB
  - 20100 – 23070 MHz: 50.0 dB
  - 23070 – 23120 MHz: 26.1 dB
  - 23535 – 23550 MHz: 34.3 dB
  - 23550 – 24400 MHz: 37.9 dB
  - 24400 – 25250 MHz: 69.8 dB
  - 25250 – 26550 MHz: 68.3 dB
  - 26550 – 27010 MHz: 84.0 dB
  - 27010 – 27500 MHz: 72.1 dB
  - 27500 – 30000 MHz: 68.5 dB

3.16 Inter-Orbit link Antenna (IOLA)

This assembly has the main function to provide the TX/RX communication link at both S-band and Ka-band using the steering of the reflector around its focus within a field characterized by a circular angular zone with half-cone angle of about 10.5°, around the central reference direction coincident with the yaw axis of the spacecraft.
Though a simultaneous access in S and Ka-band is not foreseen in AD1, S-band user sessions and Ka-band user sessions could be simultaneous only in RX, but with some degradation on the performances.
The IOLA assembly is composed of the following main equipments:

- Reflector dish
- Hold down and release mechanism
- Antenna deployment mechanism
- IOL radiating horn
- IOL RF sensing network
- IOL S-band polarizer and switches.

The SKDR IOL antenna consists of a parabolic reflector with offset illumination feed (S+K-band) and a RF sensor in Ka-band. The optics geometry is an offset paraboloid with an aperture diameter of 2.85 m.
The tracking movements allow the rotation of the reflector about the focus around two orthogonal axes, being the feed fixed and mounted on the west sidewall of the spacecraft. The movements of the reflector are actuated by means of a two axes Antenna Pointing Mechanism (APM) and a suitable supporting arm.

Performance characteristics:

- Frequency bands:
    - 2025 – 2110 MHz S-band TX
    - 2200 – 2290 MHz S-band RX
    - 23120 – 23550 MHz Ka-band TX
    - 25250 – 27500 MHz Ka-band RX

- Gain (peak gain)
    - 32.6 dBi S-band TX (@ 10.7° scan angle)
    - 33.6 dBi S-band RX (@ 6° scan angle)
    - 33.3 dBi S-band RX (@ 10.7° scan angle)
    - 52.9 dBi Ka-band TX
    - 53.0 dBi Ka-band RX

- Polarization: RHCP / LHCP selectable

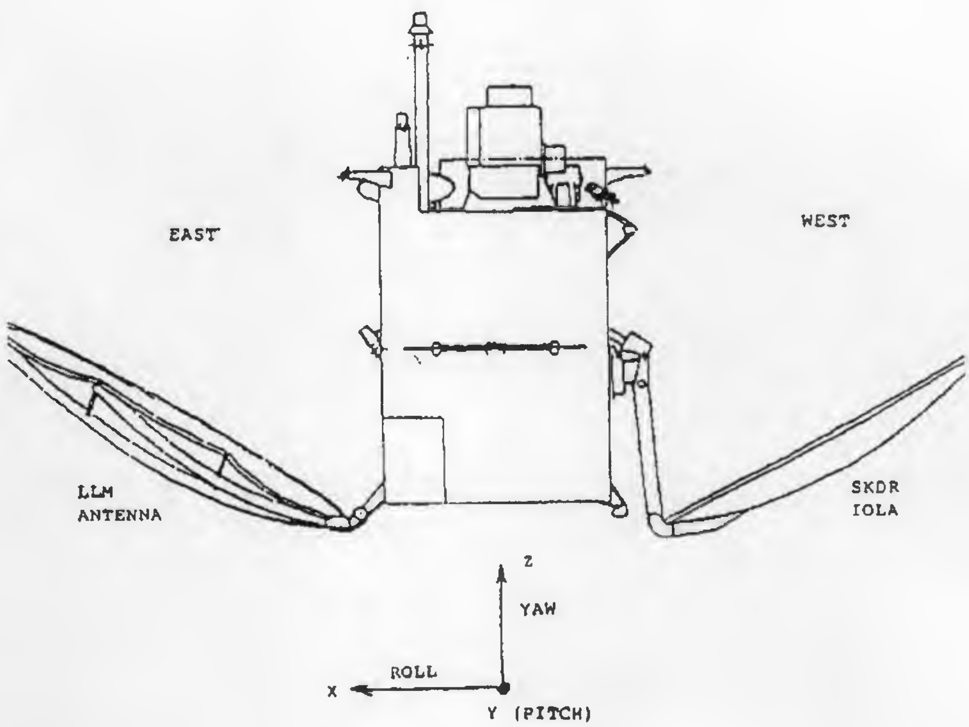


Figure 16 IOLA outline

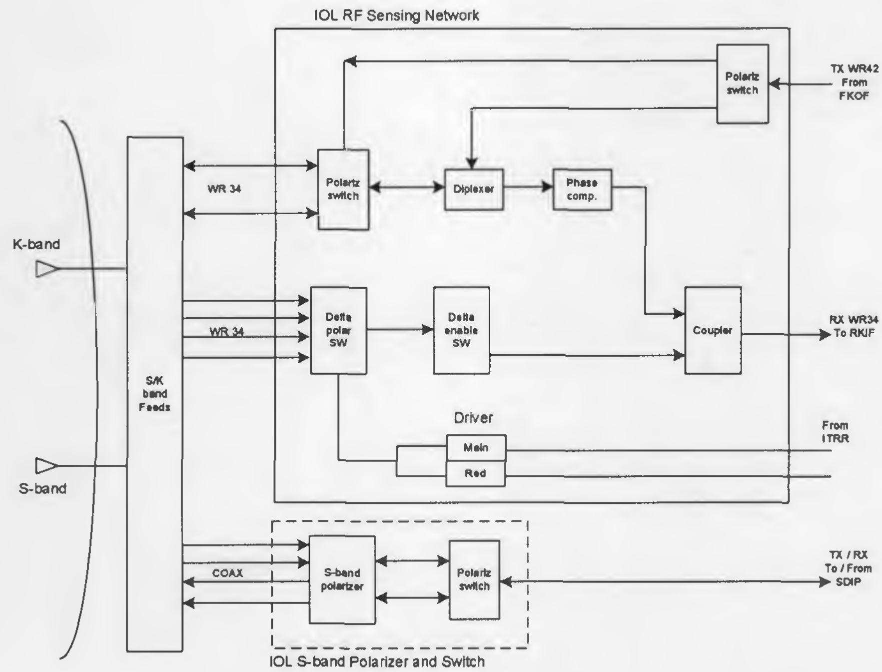


Figure 17 IOLA block diagram

3.17 IOL Antenna Pointing System (APS)

The APS is dedicated to point the IOL antenna of ARTEMIS SKDR payload towards a given user in low orbit, in order to acquire and maintain the communication link, either in S-band, or in Ka-band by means of reflector rotation around its focus whereas the feed is kept fixed on the spacecraft panel.

At S-band frequencies, the pointing towards the LEO user is performed without RF sensing in program track mode and is driven by the antenna pointing controller onboard processor (APC) by means of the two axes APM, using time tagged user position data provided in advance from ground.

At Ka-band frequencies, the pointing towards the LEO user is performed either in program track mode, as in S-band, or in auto-track mode which is the main mode.

The tracking mode uses RF sensors integrated in the Ka-band antenna feed, which provide the pointing error functions for the acquisition and tracking control loops.
The APS is composed of three major functional components:

- Antenna pointing controller (APC)
- IOL antenna pointing assembly (APA)
- Tracking receiver (ITRR)

The ITRR has the following main functions:

- Detection of RF signal amplitude level in each of the four lobe positions;
- Measurement of the power level from lobe to lobe position;
- Generation of timing signals to the antenna RF sensor.

The IF filter shall be selectable under command from the APC, depending on the RF return signal BPSK modulation data rate. The way the filter bandwidth is chosen is summarized in the following table.

PSK data rate	Filter BW	Filter number
2 - 100 ksps	100 kHz	1
100 - 200 ksps	200 kHz	2
200 - 400 ksps	400 kHz	3
400 - 800 ksps	800 kHz	4
800 - 1600 ksps	1.6 MHz	5
1.6 - 3.2 Msps	3.2 MHz	6
3.2 - 6.4 Msps	6.4 MHz	7
6.4 - 12.8 Msps	12.8 MHz	8
12.8 - 25.6 Msps	25.6 MHz	9
25.6 - 51.5 Msps	51.2 MHz	10
51.2 - 102.4 Msps	102.4 MHz	11
102.4 - 150 Msps	204.8 MHz	12

Table 1 ITRR filter selection vs. bit rate

ITRR Performance characteristics:

- RF frequency: 5500 MHz +/- 2 MHz
- Phase modulation: BPSK
- Bit rate: 2 ksymbol/s to 150 Msymbol/s
- Detection bandwidth range: 100 kHz to 204.8 MHz (selectable)

APS overall performance:

- Slewing mode:
  - Max slewing time: 150 s
  - Max slewing angle: 22° for each axis
  - Angular speed: up to 0.2 °/s
  - Angular acceleration: up to 0.02 $°/s^2$

- Program track mode:
  - Pointing error S-band (TX/RX) : 0.32° (half cone) at 3σ corresponding to an interval of confidence of 99.74 %
  - Pointing error Ka-band RX : 0.11° (half cone) at 1σ corresponding to an interval of confidence of 70 %.
  - Pointing error Ka-band TX : 0.18° (half cone) at 1σ corresponding to an interval of confidence of 70 %.

- Acquisition mode:
  - The accuracy of knowledge of the starting pointing condition must be within 0.33° at 3σ, which is the open loop pointing error in RX
  - Angular acquisition time (99% probability): 62 s mean, 85 s max
  - Angular acquisition time (99.9% probability): 62 s mean, 120 s max

  This performance is achieved when the acquisition starts from a pointing condition anywhere (but known) within a full cone angle of 2° and centre line from ARTEMIS to UST. A pre-slew or program track manoeuvre is performed to reduce the mispointing within the unknown pointing error of 0.33° at 3σ.

- Tracking mode:
  - Autotrack error at 3σ in RX: < 0.03°
  - Autotrack error at 3σ in TX: < 0.11°

3.18 Return Ka-band Input Filter (RKIF)

The unit is a 9 poles band pass filter with Tchebyshev response operating on the 25.25 – 27.5 GHz frequency range.
It is connected to the RX antenna and to the 26 GHz LNA, through a transfer switch (RKIS).

The main characteristics are:

- useful bandwidth: 2250 MHz
- Frequency range: 25.25 to 27.5 GHz

3.19 Return Ka-band Low noise Amplifier (RKLA)

The 26 GHz Front-End is a very low noise receiver which amplifies at fixed gain the incoming signals in the return link section.
The overall equipment mainly consists of the following parts (see figure 18):

- A wave guide isolator at each port.
- Two cold redundant amplifying chains.
- An output coupler to feed the output port.
- Two cold redundant power supply modules.
- Two cold redundant biasing and temperature compensation modules.
- A wave guide band pass filter to provide out-of-band rejection.

The main characteristics are:

- Gain: 40 +/- 0.25 dB
- Gain stability: < 1 dBpp
- Noise figure: 3 dB
- Frequency range: 25.25 to 27.5 GHz

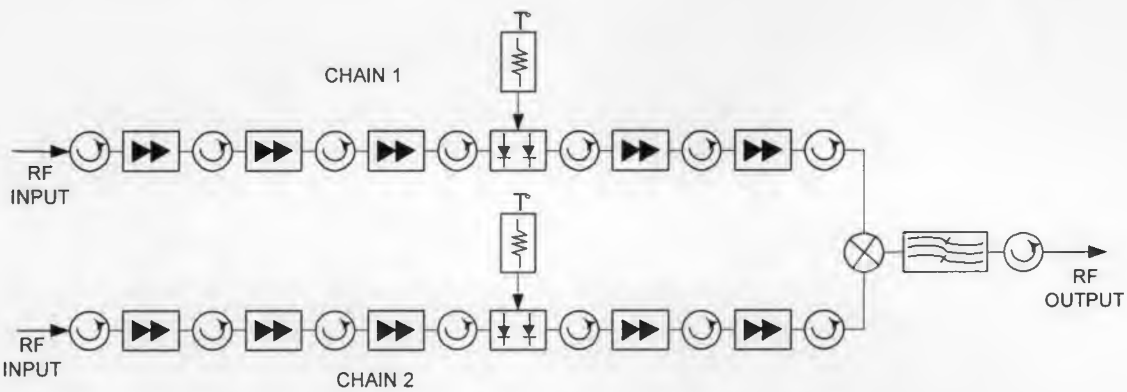


Figure 18 RKLA block diagram

3.20 Return 26/5.5 GHz Frequency Converter (RKIC) + Filter (RKSF)

The units are used to convert one of the multiple received 26 GHz RF channels to a fixed IF output of 5.5 GHz.
The units (depicted in figure 19) consist of:

- A mixer module;
- A tunable telecommandable local oscillator adjustable in steps of 250 MHz after the frequency doubler.
- A wide band 5.5 GHz amplifier;
- A DC/DC converter to supply the subunit with a well stabilized voltage.

Spur filters (RKSF) have been included into the harness between the power splitter (RKPD) and the down-converters RKIC-A and RKIC-C in order to attenuate the unwanted mixing products in a

RKIC due to LO (and 2 x LO) signal from the neighbour RKIC. These filters are described here below:

- Low pass filters, tapered corrugated
- No tuning
- Silver plated aluminium

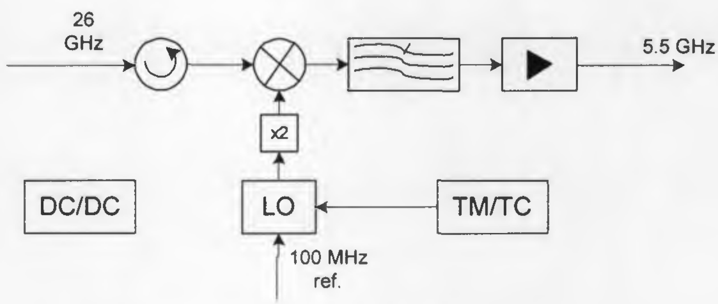


Figure 19 RKIC block diagram

The main characteristics of the RKIC are given below:

- Input frequency range: 25.60 to 27.35 GHz
- LO frequency range and step: 10050 to 10925 MHz by steps of 125 MHz
- Gain: 10 +/- 0.5 dB (@ BOL)
- RKSF useful bandwidth: 2050 MHz

3.21 *Return 5.5 GHz Wideband Filter (RIWF)*

The 5.5 GHz channel band pass filter is a self equalised quasi elliptic filtering characteristics type. Seven equal filters are required per SKDR payload. They are located respectively:

- three filters at the outputs of the three K-band down-converters (RKIC);
- four filters at the outputs of the RICS switches network.

Main characteristics:

- nominal centre frequency (f0): 5.5 GHz
- useful channel bandwidth: 200 MHz

3.22 *Return 5.5 GHz Narrowband Filter (RINF)*

the 5.5 GHz IF channel band pass filter is put at the output of the return link down-converter (RKIC-C) to suppress mixer products, out-of-band noise and other interfering signals. In order to enhance the linearity of the group delay, the external equalization solution has been utilized. The schematic block diagram is shown in the following figure.

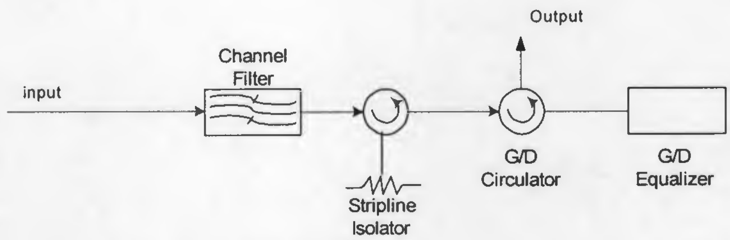


Figure 20 RINF block diagram

Main characteristics:

- nominal centre frequency (f0): 5.5 GHz
- useful channel bandwidth: 30 MHz

3.23 *Return 5.5 GHz Optical BPSK Modulator (ROMD)*

The return 5.5 GHz optical BPSK modulator consists of two redundant units which outputs are coupled to a common output interface by a Wilkinson coupler as illustrated in the block diagram depicted in figure 21.
Each unit is composed of four functional modules:

- Differential and convolutional encoder;
- Data shaping driver;
- Mixer modulator;
- DC/DC converter.

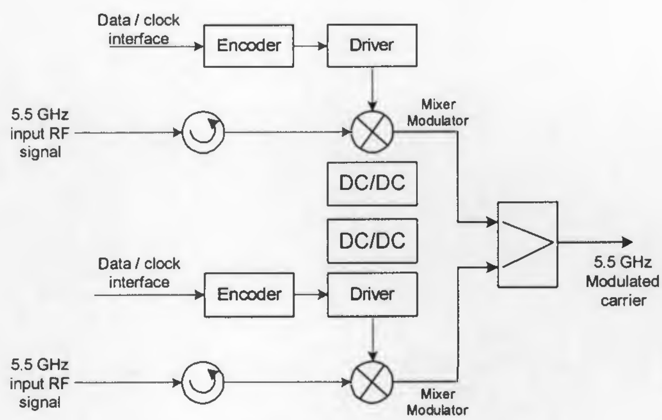


Figure 21 ROMD block diagram

Main characteristics:

- Carrier frequency: 5.5 GHz
- Modulation: BPSK
- Phase imbalance: < 6 degree
- Data bit Jitter: < 2%
- Half rate encoding
- Differential encoding
- Data rate: 49.3724 Mbps

3.24 Return 2/5.5 GHz Receiver (RSIR)

The RSIR unit is a 2/5.5 GHz receiver providing single step frequency up-conversion of one channel from selectable input frequency in the 2.2 GHz range to a fixed output frequency of 5.5 GHz.

The equipment consists of (see figure 22):

- A low loss input isolator;
- A three stage 2.2 GHz low noise HEMT amplifier;
- A 2.2 GHz filter to reject the forward S-band frequencies.
- A mixer module equipped with its output filter;
- A tunable LO adjustable by telecommand in steps of 0.5 MHz and driven by an external 100 MHz signal, its frequency range starts at 3210 MHz and ends at 3300 MHz.
- A double stage 5.5 GHz amplifier;
- A 5.5 GHz attenuator to maintain the gain constant in temperature;
- An output isolator;
- A DC/DC converter power supply.

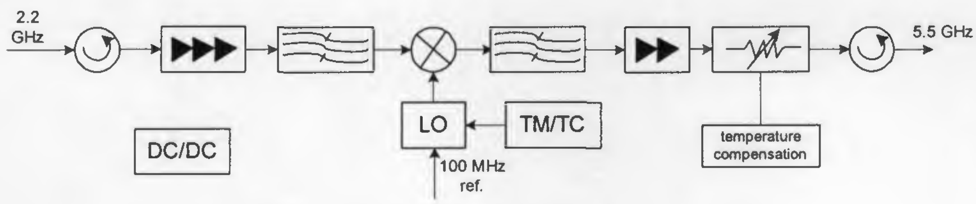


Figure 22 RSIR Block diagram

Main performance characteristics:

- Input frequency range: 2200 – 2290 MHz
- Frequency step: 0.5 MHz
- Useful channel bandwidth: 12 MHz
- Output centre frequency: 5.5 GHz

3.25 Return 5.5 GHz Channel Filter (RISF)

The 5.5 GHz channel filter is put at the output of the S-band receivers (RSIR) to prevent spurious transmission in the return link.
The unit, externally equalized, consists of:

- low pass filter;
- channel filter;
- isolator;
- group delay circulator;
- group delay equalizer.

The schematic block diagram is depicted in figure 23.

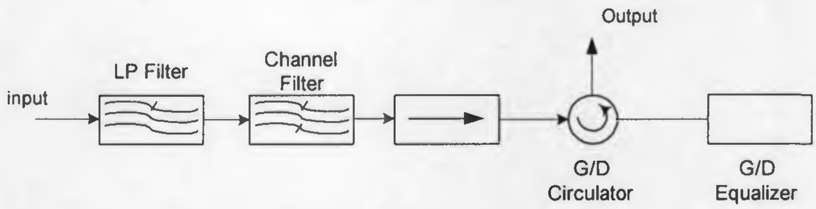


Figure 23 RISF block diagram

Main performance characteristics:

- nominal centre frequency: 5.5 GHz
- channel bandwidth: 8.8 MHz

3.26 *Return 5.5 GHz Channel Amplifier (RICA)*

The overall equipment is a C-band channel amplifier operating at a centre frequency of 5.5 GHz with an operating bandwidth of 200 MHz. It is able to cope with a wide input power range from –66 dBm to –26 dBm in an ALC mode. The output is settable by telecommand in a range from –50 dBm to –15 dBm in order to set the following TWTA at different operating points and so to change the repeater output power. There is no telecommand to disable the ALC.
Four units are provided in the SKDR payload system.

The main characteristics are:

- Channel centre frequency (f0): 5.5 GHz
- Output Power setting (by TC) range: -50 to –15 dBm.
- Step width: 0.6 dB
- Number of steps: 64

3.27 *Return 5.5 / 20 GHz Frequency Converter (RIKC)*

The equipment provides single step frequency up-conversion of one channel from a fixed 5.5 GHz input frequency to a dedicated channel output frequency in the 20 GHz band (Return Feeder Link channel).
Four equipments are used in the return feeder link towards earth station.

The equipment consists of:

- A mixer module;
- A local oscillator
- A DC/DC converter to supply the subunit with a well stabilized voltage.
- The unit is driven by a 100 MHz reference signal from a Central Reference Frequency Unit (FRGU).

The block diagram of this equipment is given in the following figure:

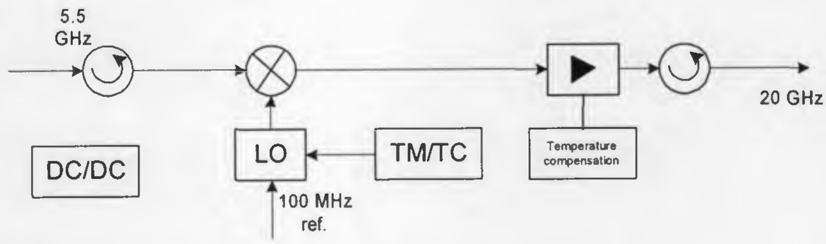


Figure 24 RIKC block diagram

The main characteristics are:

- Input centre frequency: 5.5 GHz
- Output channel frequencies:
  - 18350 MHz (channel 1)
  - 18600 MHz (channel 2)
  - 18850 MHz (channel 3)
  - 19100 MHz (channel 4)
- useful channel bandwidth: 200 MHz

3.28 Return Ka-band Travelling Wave Tube Amplifier (RKPA)

The equipment is a Ka-band Travelling Wave Tube Amplifier (TWTA) providing a saturated output power in the range of 30 W.
It consists of the TWT proper, the EPC and the high voltage interconnection cable.
The 20 GHz TWTA provides power amplification of the signal in the return feeder link section towards the earth station.

Main characteristics:

- Operating frequency range:
  - 18350 MHz (channel 1)
  - 18600 MHz (channel 2)
  - 18850 MHz (channel 3)
  - 19100 MHz (channel 4)
- saturation gain: 57 to 60 dB
- saturated output power: 30 W

3.29 *Return 20 GHz Output Multiplexer (RKOM)*

The equipment is used to combine the SKDR signals to be transmitted in the return feeder link towards earth station. It is a manifold output multiplexer that combines four communication channels and two telemetry channels.
Each input path comprises a low pass and a band pass filter.

The main characteristics are:

- operating frequency range: 18.1 – 20.2 GHz
- useful channel bandwidth:
  - 200 MHz (communication channels)
  - 8 MHz (MTM)
  - 26 MHz (TM + Pilot)

4 CHANNELS CHARACTERISTICS

The ARTEMIS Data Relay payload was measured from Redu, in the period February to March 2003. The reader will find in the following paragraphs the summary of the SKDR payload essential performances.
All the data given hereafter are related to links Redu-ARTEMIS-Redu, taking 38600 km as reference for the distance between ARTEMIS and Redu station. A full link budget must be computed for every user in order to take into account every parameter of interest.

4.1 *S-band Data Relay payload*

4.1.1 FORWARD 30/2.0 GHZ CHANNEL

4.1.1.1 *Receive G/T at 30 GHz.*

The forward feeder link antenna G/T was measured from Redu in different configurations and the results were in the range 13.59 to 15.27 dB/K. In other words, the G/T at 30 GHz is better than 13.59 dB/K.

4.1.1.2 *30 GHz nominal receive power and power range.*

The onboard ALC has a wide range and keeps the downlink EIRP constant. In AD1, it is stated that the nominal Up-link C/N_0 should be kept in the range 80 to 115 dBHz. This corresponds to an up-link EIRP range of 51.9 to 86.9 dBW (taking a G/T of 13.59 dBK^{-1} into account and a TX frequency of 29 GHz).
The forward feeder link antenna coverage map is given in appendix B.

4.1.1.3 2.0 GHz Downlink EIRP.

The EIRP is settable by telecommand in steps of less than 2 dB from 21.0 dBW to 45 dBW and in steps of less than 1 dB from 45 dBW to 48.4 dBW. Based on this measured values and according to AD5 the nominal EIRP will be fixed at 41 dBW with the appropriate gain setting on the FSPA. 45 dBW is also allowed but should be restricted to periods when the UST is higher than 2 degrees from the Earth's horizon as seen by ARTEMIS.

4.1.1.4 Channel gain setting.

As mentioned in the previous paragraph, it is possible to set the down-link EIRP with operational gain offset of –20 to +7 dB around the nominal channel gain.
The following figure shows the typical relation between gain setting and EIRP of FSPA-1.

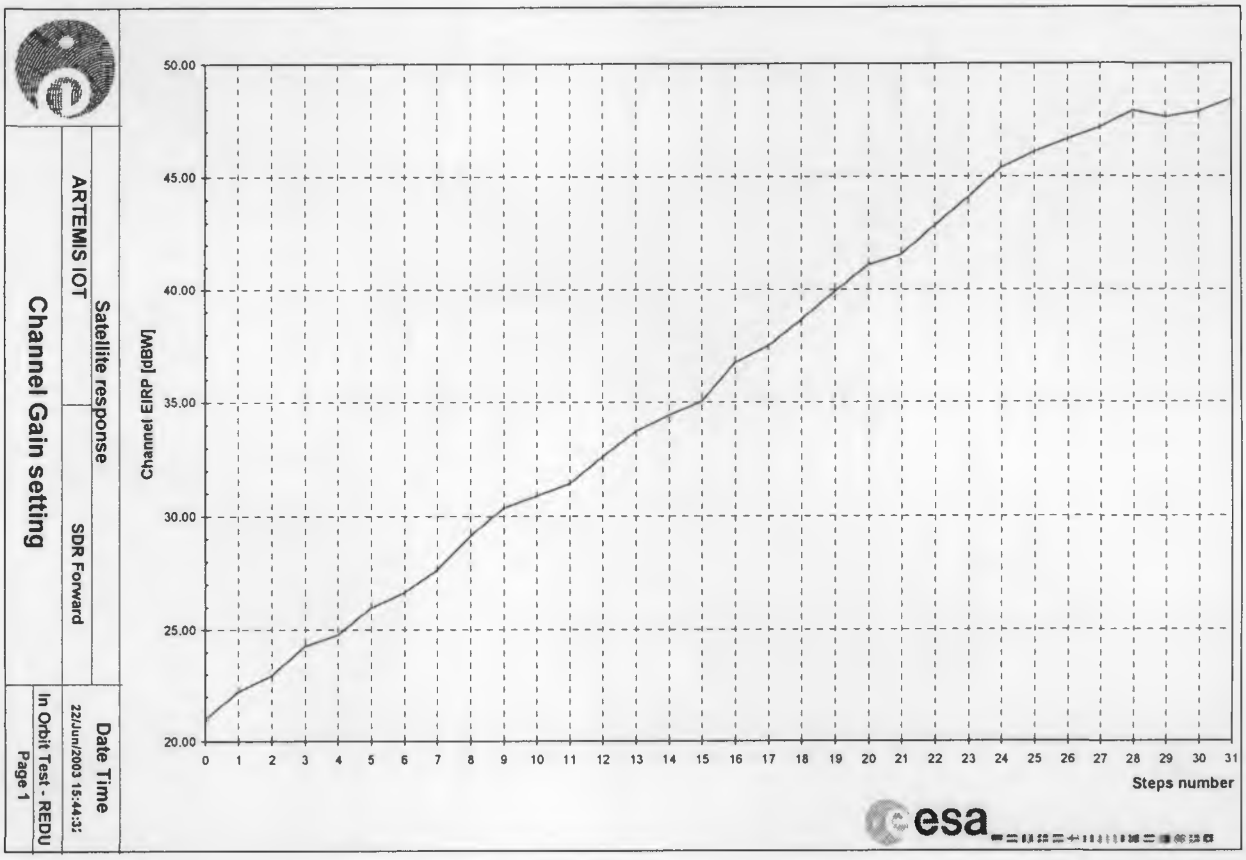


Figure 25 FSPA-1 EIRP vs. gain setting

4.1.1.5 Gain versus frequency characteristics

The frequency response is defined normally by a simple and unique filter at 5.5 GHz intermediate frequency (FISF). All other units have much higher bandwidths.
The following figure shows the typical channel noise frequency response, corrected for receive station gain versus frequency response:

Figure 26 30/2 GHz channel (S-FWD) gain / frequency response

4.1.2 RETURN 2.2 / 20 GHZ CHANNEL

4.1.2.1 Receive G/T at 2.2 GHz

The return IOL antenna G/T was measured from Redu in different configurations and the results were in the range 7.8 to 8.5 dB/K. In other words, the G/T at 2.2 GHz is better than 7.8 dB/K

4.1.2.2 2.2 GHz nominal receive power and power range.

In AD1, it is stated that the nominal Up-link C/N_0 should be kept in the range 25 to 85 dBHz. This corresponds to an up-link EIRP range of 39.4 to –20.6 dBW (taking a G/T of 8.5 dBK^{-1} into account and a TX frequency of 2.25 GHz).
The corresponding IPFD range is then from –183.5 to –123.5 dBW/m^2.

4.1.2.3 20 GHz downlink EIRP.

The 20 GHz feeder link EIRP is in principle only depending on the output amplifier (RKPA).
The maximum EIRP available is 51 dBW (over Redu).
This parameter is also settable by telecommand over a range of 33 dB by steps of less than 1 dB.
The return feeder link antenna coverage map is given in appendix C.

4.1.2.4 Channel gain setting

The return feeder link EIRP shall be set to any value, $EIRP_{set}$ meeting the relation:

$$[C / C_{ref}]_{dB} + (EIRP_{ref} - EIRP_{set}) \leq 60 \text{ dB}$$

Where

- C is the carrier power at the antenna feed flange resulting from the power flux and C_{ref} is the carrier power at the antenna feed flange resulting in a C/N_0 equal to 40 dBHz.
- $EIRP_{ref}$ is the channel EIRP in the direction of the UET (44.2 dBW @Redu defined in AD1).
- $EIRP_{set}$ is the channel EIRP set by telecommand, i.e. $-6.8 \leq (EIRP_{ref} - EIRP_{set}) \leq 23.8$
- The ratio C / C_{ref} should be lying in the range –6 to 40.8 dB.

A typical curve of the EIRP vs. gain setting is given in the following figure.

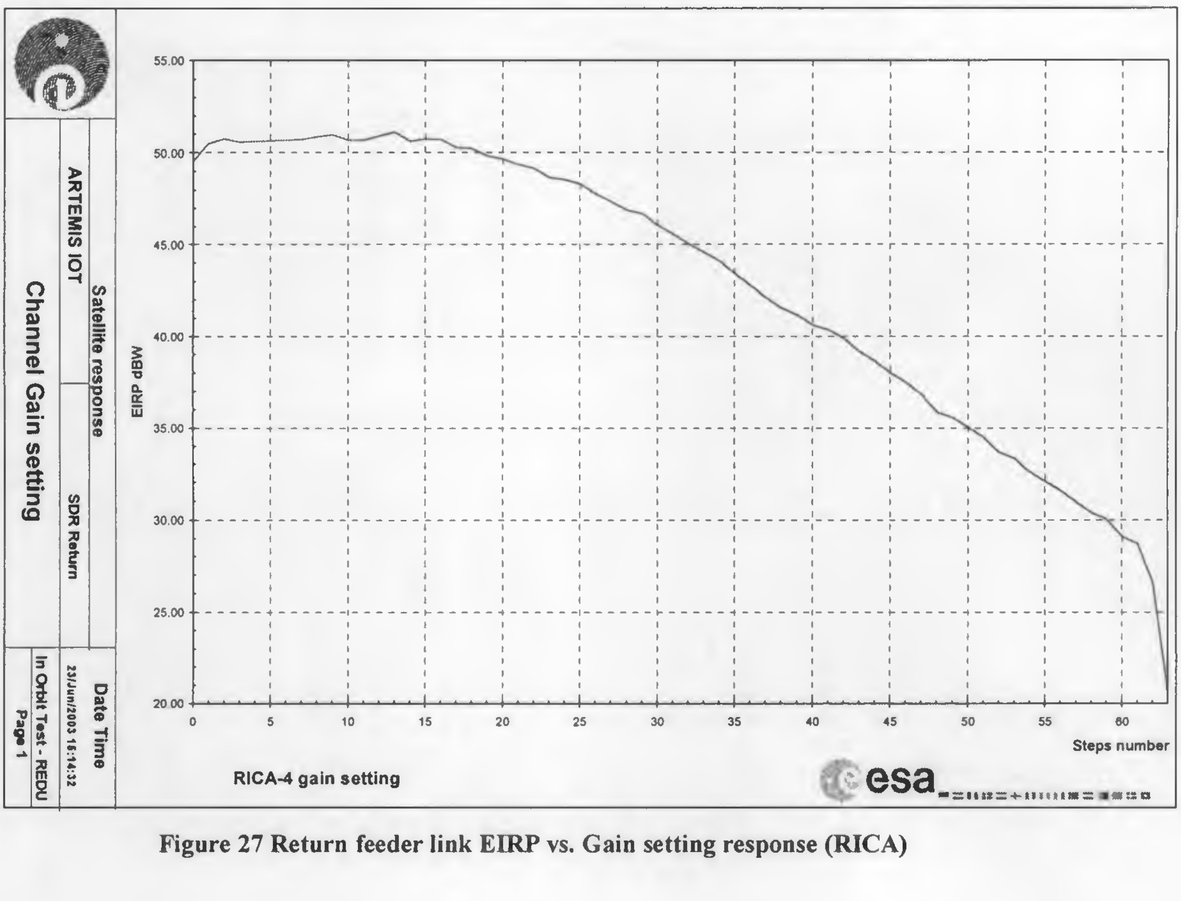


Figure 27 Return feeder link EIRP vs. Gain setting response (RICA)

4.1.2.5 Gain versus frequency characteristics

The frequency response is defined by a unique filter at 5.5 GHz intermediate frequency (RISF). All other units have much higher bandwidths.
The following figure shows the channel noise frequency response, corrected for receive station gain versus frequency response:

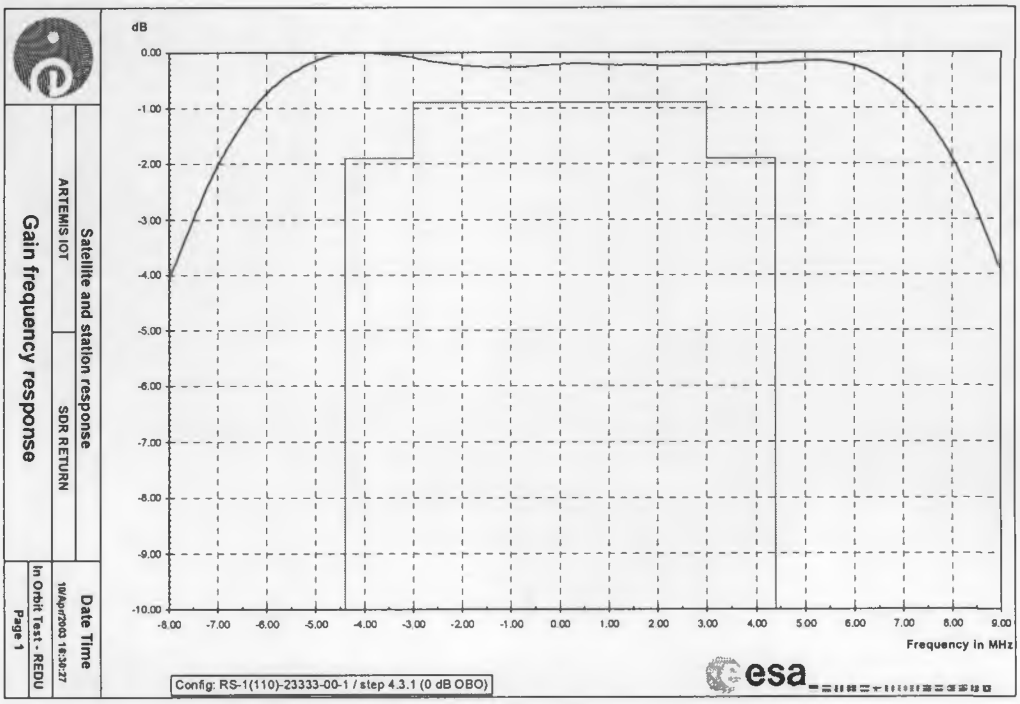


Figure 28 20 / 2.2 GHz channel gain/frequency response

4.2 Ka band data relay payload

4.2.1 FORWARD 30 / 23 GHZ CHANNEL

4.2.1.1 Receive G/T at 30 GHz

The forward feeder link antenna G/T was measured from Redu in different configurations and the results were in the range 13.59 to 15.27 dB/K. In other words, the G/T at 30 GHz is better than 13.59 dB/K.

4.2.1.2 30 GHz nominal receive power and power range.

The onboard ALC has a wide range and keeps the downlink EIRP constant. In AD1, it is stated that the nominal Up-link C/N_0 should be kept in the range 80 to 115 dBHz. This corresponds to an up-link EIRP range of 51.9 to 86.9 dBW (taking a G/T of 13.59 dBK^{-1} into account and a TX frequency of 29 GHz).
The forward feeder link antenna coverage map is given in appendix B.

4.2.1.3 23 GHz Downlink EIRP.

The maximum recorded EIRP is 65 dBW (at Redu). The signal applied to the output amplifier is first levelled by an ALC and can be adjusted by telecommand in the FICA unit.

4.2.1.4 Channel gain setting

The EIRP is settable in the range 41 to 65 dBW by step of less than 1 dB (63 steps total). The following figure shows a typical EIRP evolution versus the gain steps number. The EIRP towards UST should be set to (AD1):

- 48.3 dBW for any symbol rate between 1ksymbol/s to 500 ksymbol/s
- 48.3 + 10log(symbol rate / 1 Msymbol/s) for any symbol rate from 500 ksymbol/s to 10 Msymbol/s.

Figure 29 FICA EIRP vs. gain setting.

4.2.1.5 Gain versus frequency characteristics

The frequency response is defined normally by a simple and unique filter at 5.5 GHz intermediate frequency (FISF). All other units have much higher bandwidths.

The following figure shows a typical channel noise frequency response, corrected for receive station gain versus frequency response:

4.2.2 RETURN 26 / 20 GHZ CHANNEL

4.2.2.1 Receive G/T at 26 GHz

The return IOL antenna G/T was measured from Redu in different configurations and the results are in the range 24.4 to 27.1 dB/K. In other words, the G/T at 26 GHz is better than 24.4 dB/K

4.2.2.2 26 GHz nominal receive power and power range.

The channel will meet the specifications when the input signal power flux is anywhere between the level corresponding to a C/N0 in the range 35 to 90 dBHz.. This corresponds to an up-link EIRP range of –4.9 dBW to 50.1 dBW taking a G/T minimum of 24.4 dBK^{-1} and a frequency of 26 GHz.

4.2.2.3 20 GHz Downlink EIRP.

The 20 GHz feeder link EIRP is in principle only depending on the output amplifier (RKPA).
The maximum EIRP available is 51 dBW.
This parameter is also settable by telecommand over a range of 33 dB by steps of less than 1 dB.
The return feeder link antenna coverage map is given in appendix C.

4.2.2.4 Channel gain setting

The return feeder link EIRP shall be set by telecommand to 44.2 dBW (over Redu) for all symbol rates greater than 1 Msymbol/s. for other symbol rates, please refer to the following table:

Symbol rate	EIRP set
> 1 Msymbol/s	44.2 dBW max
Between 10 ksymbol/s and 1 Msymbol/s	Between max and -15.9 + 10 log(symbol rate) dBW
Between 2 ksymbol/s and 10 ksymbol/s	Between max and 24.2 dBW

A typical curve of the EIRP vs. gain setting is given in the following figure.

Figure 30 RICA EIRP vs. gain setting.

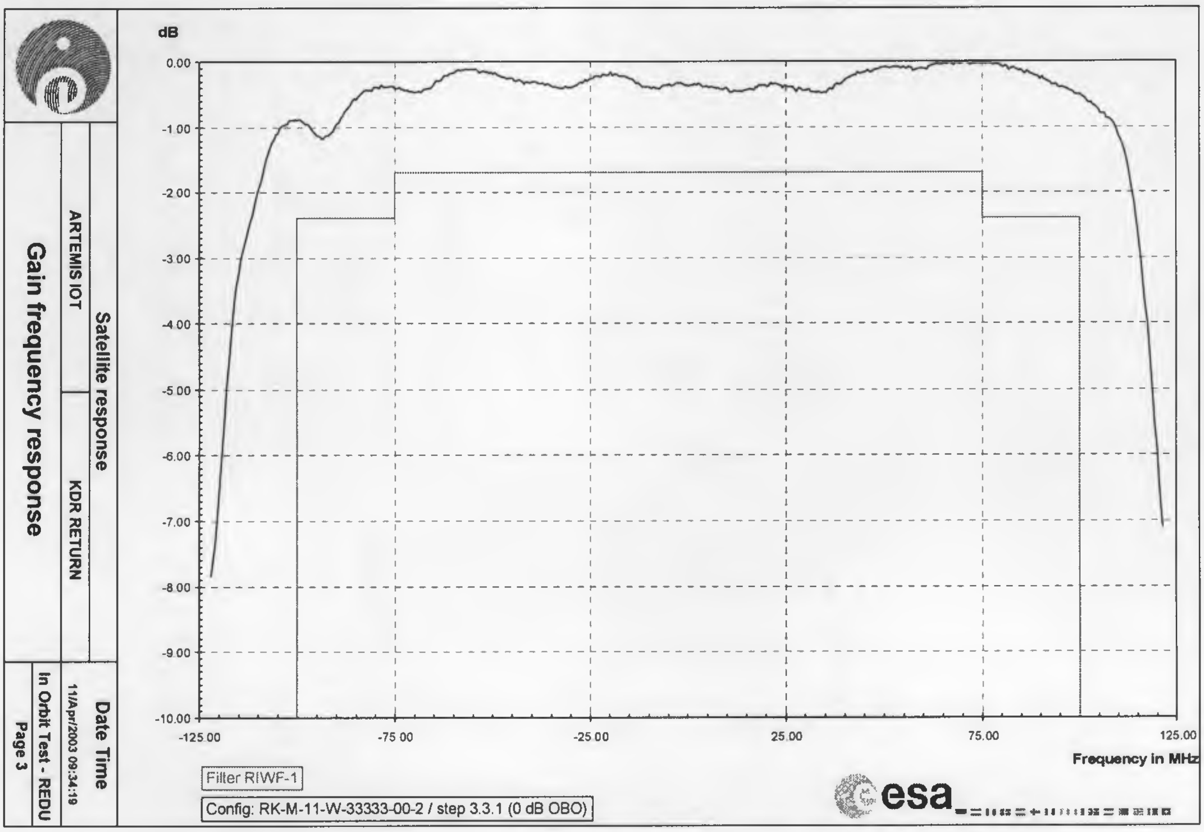
4.2.2.5 Gain versus frequency characteristics

4.2.2.5.1 Narrow band channel

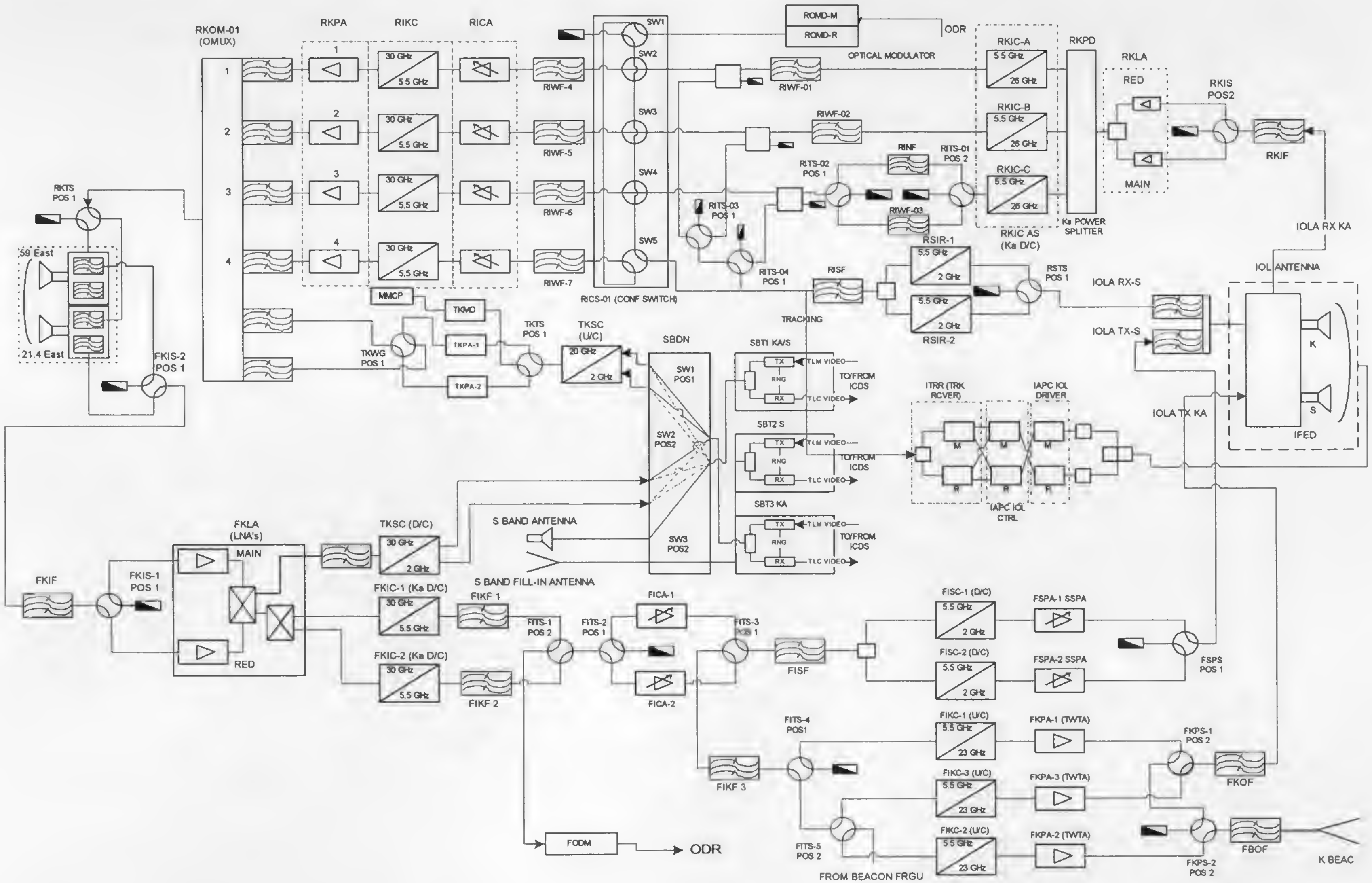
The frequency response is defined by a filter at 5.5 GHz intermediate frequency RINF. The following figure shows the channel noise frequency response, corrected for receive station gain versus frequency response:

4.2.2.5.2 *Wide band channel*

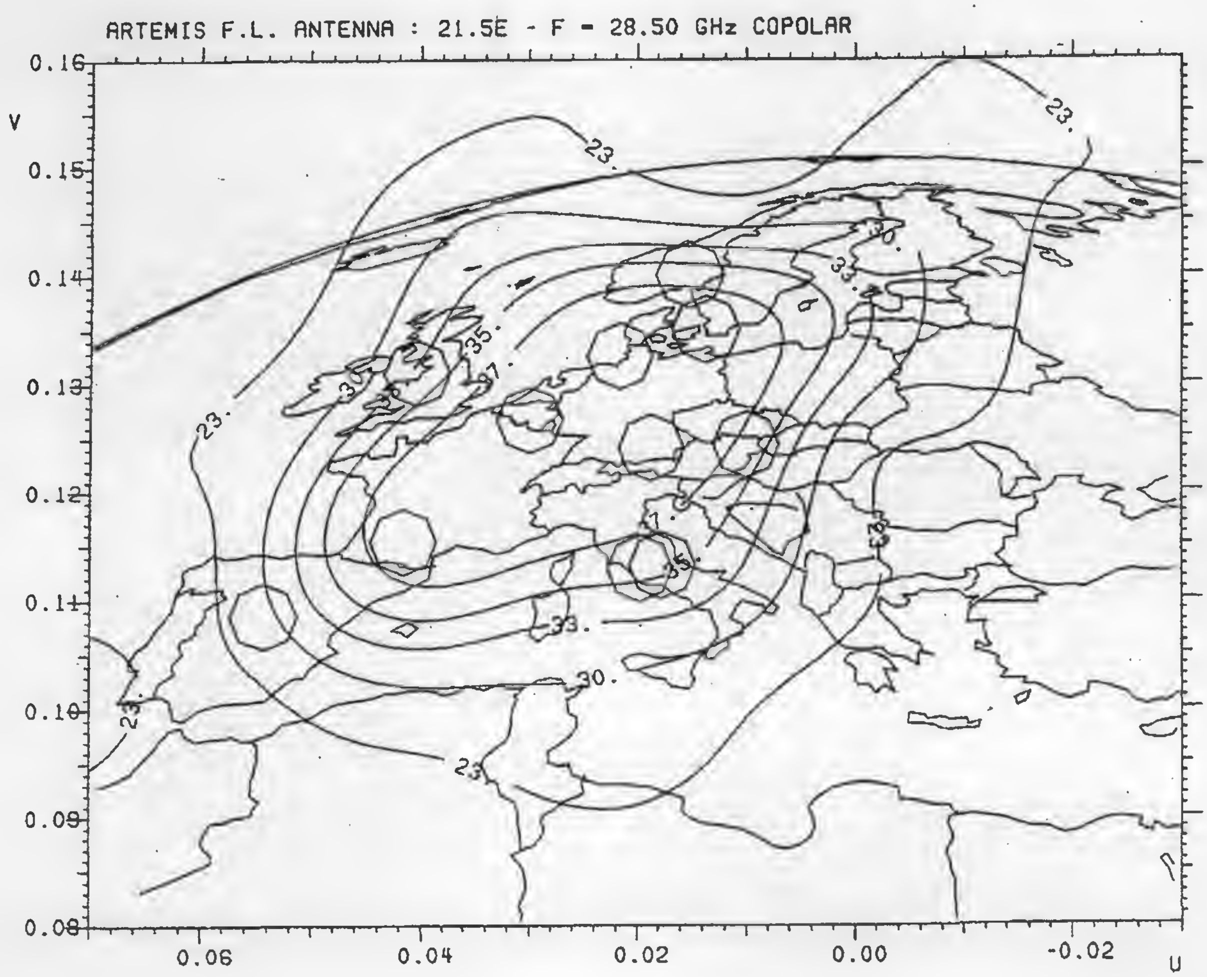
The frequency response is defined by a filter at 5.5 GHz intermediate frequency (RIWF 1 to 3). All other units have wider bandwidths.



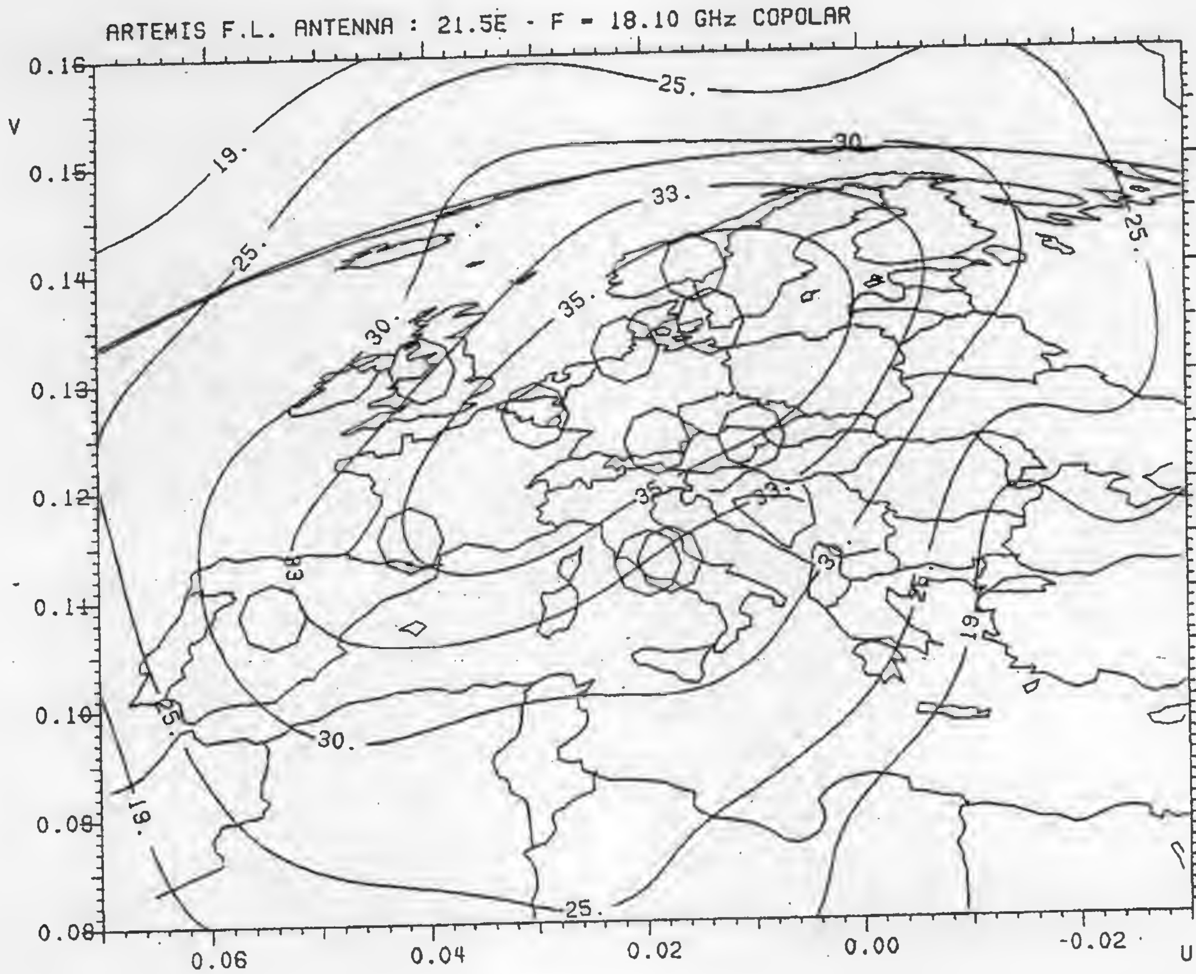
5 APPENDIX A DATA RELAY PAYLOAD BLOCK DIAGRAM



6 APPENDIX B FORWARD FEEDER LINK ANTENNA COVERAGE MAP



7 APPENDIX C RETURN FEEDER LINK ANTENNA COVAGE MAP



8 APPENDIX D TYPICAL LINK BUDGET SAMPLES

This link budget is given as an example only

ARTEMIS Data Relay Link Budget			
S-band Forward Link 2 kbps			
UST in circular orbit 400 km altitude, ARTEMIS in geostationary orbit at 21.5 E, EET in Redu, Belgium			
Parameter	Units		
Availability		0.999	
Bit Error Rate		10 E-6	
Modulation		UQPSK	
Coding		half rate	
Information Data Rate	b/s	2000	
Theoritical Required Ei/N0	dB	4.2	
DRSS Noise Bandwidth	MHz	12	
		EET -> ARTEMIS	ARTEMIS -> UST
Frequency	MHz	28650.0	2055.0
EIRP	dBW		48.0
TWTA Output Backoff	dB		7.0
Modulation + truncation Loss	dB		0.7
Power Sharing Loss	dB		0.0
Signal EIRP towards Receiver	dBW	81.0	40.3
Space distance	km	38500.0	42500.0
Free Space Loss	dB	213.3	191.5
Atmospheric Attenuation	dB	13.0	0.0
Polarisation Loss	dB	0.1	0.3
G/T towards Transmitter	dB/K	13.6	0.0
C/N0	dBHz	96.8	77.9
Ei/N0	dB	63.7	44.9
C/N in DRSS	dB	26.0	
Power Flux Density at receiver Antenna	dBW/m²	-94.8	-123.3
Overall Link C/N0	dBHz		77.8
Overall Link Ei/N0	dB		44.8
Total Link Degradation	dB		3.0
Resulting Ei/N0	dB		41.8
System Margin	dB		37.6

This link budget is given as an example only.

ARTEMIS Data Relay Link Budget			
S-band Return Link 4096 bps			
UST in circular orbit 400 km altitude, ARTEMIS in geostationary orbit at 21.5 E, EET in Redu, Belgium			
Parameter	Units		
Availability		0.999	
Bit Error Rate		10 E-6	
Modulation		UQPSK	
Coding		half rate	
Information Data Rate	b/s	4096	
Theoritical Required Ei/N0	dB	4.2	
DRSS Noise Bandwidth	MHz	12	
		UST -> ARTEMIS	ARTEMIS -> EET
Frequency	MHz	2255	18350
EIRP	dBW		51
TWTA Output Backoff	dB		6.8
Modulation + truncation Loss	dB		0.7
Power Sharing Loss	dB		16.82
Signal EIRP towards Receiver	dBW	10	26.68
Space distance	km	42500	38500
Free Space Loss	dB	192.1	209.43
Atmospheric Attenuation	dB	0	6.5
Polarisation Loss	dB	0.25	0.1
G/T towards Transmitter	dB/K	7.8	42.5
C/N0	dBHz	54.07	81.72
Ei/N0	dB	17.95	45.59
C/N in DRSS	dB	-16.73	
Power Flux Density at receiver Antenna	dBW/m²	-153.81	-125.7
Overall Link C/N0	dBHz		54.06
Overall Link Ei/N0	dB		17.9
Total Link Degradation	dB		2
I:Q loss (1:1)	dB		3
Resulting Ei/N0	dB		12.9
System Margin	dB		8.7

This link budget is given as an example only

ARTEMIS Data Relay Link Budget			
K-band Forward Link 1 Mbps			
UST in circular orbit 400 km altitude, ARTEMIS in geostationary orbit at 21.5 E, EET in Redu, Belgium			
Parameter	Units		
Availability		0.999	
Bit Error Rate		10 E-6	
Modulation		BPSK	
Coding		-	
Information Data Rate	b/s	1000000	
Theoritical Required Ei/N0	dB	10.6	
DRSS Noise Bandwidth	MHz	50	
		EET -> ARTEMIS	ARTEMIS -> UST
Frequency	MHz	28650.0	23350.0
EIRP	dBW		65.0
TWTA Output Backoff	dB		16.7
Modulation + truncation Loss	dB		0.2
Power Sharing Loss	dB		0.0
Signal EIRP towards Receiver	dBW	81.0	48.1
Space distance	km	38500.0	42500.0
Free Space Loss	dB	213.3	212.4
Atmospheric Attenuation	dB	13.0	0.0
Polarisation Loss	dB	0.1	0.3
G/T towards Transmitter	dB/K	13.6	10.0
C/N0	dBHz	96.8	73.5
Ei/N0	dB	36.8	13.5
C/N in DRSS	dB	19.8	
Power Flux Density at receiver Antenna	dBW/m²	-94.8	-115.5
Overall Link C/N0	dBHz		73.5
Overall Link Ei/N0	dB		13.5
Total Link Degradation	dB		2.0
Resulting Ei/N0	dB		11.5
System Margin	dB		0.9

This link budget is given as an example only

ARTEMIS Data Relay Link Budget			
K-band Return Link 50 Mbps			
UST in circular orbit 400 km altitude, ARTEMIS in geostationary orbit at 21.5 E, EET in Redu, Belgium			
Parameter	Units		
Availability		0.999	
Bit Error Rate		10 E-6	
Modulation		BPSK	
Coding		half rate	
Information Data Rate	b/s	50000000	
Theoritical Required Ei/N0	dB	5	
DRSS Noise Bandwidth	MHz	200	
		UST -> ARTEMIS	ARTEMIS -> EET
Frequency	MHz	26000	18350
EIRP	dBW		44.7
TWTA Output Backoff	dB		0
Modulation + truncation Loss	dB		0.7
Power Sharing Loss	dB		0.9
Signal EIRP towards Receiver	dBW	50	43.1
Space distance	km	42500	38500
Free Space Loss	dB	213.32	209.43
Atmospheric Attenuation	dB	0	6.5
Polarisation Loss	dB	0.25	0.1
G/T towards Transmitter	dB/K	24.4	42.5
C/N0	dBHz	89.43	98.84
Ei/N0	dB	9.43	18.84
C/N in DRSS	dB	6.42	
Power Flux Density at receiver Antenna	dBW/m^2	-113.81	-126.2
Overall Link C/N0	dBHz		88.96
Overall Link Ei/N0	dB		8.96
Total Link Degradation	dB		2
I:Q loss (1:1)	dB		3
Resulting Ei/N0	dB		6.96
System Margin	dB		1.96