Ka Uplink Station for Skylogic
Design Criteria and Earth Station Engineering

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Abstract
This paper describes the Design Criteria and the Earth Station Engineering for the Provision of a Ka Band Tx/Rx Uplink for Skylogic (company of Eutelsat) in Turin (Italy). The Ka Uplink is provided by Aersat to Skylogic with commissioning phase planned at the end of July 2004. The Aersat is fully responsible for the Project in cooperation with Antech in charge either for the provision of the 5m Ka Tracked Antenna either for the Equipment Integration on site.

The proposed system is constituted by a Ka band Earth Station operating with the Eutelsat W3A satellite located at 7° East. The W3A satellite, besides to constitute the back-up to the Eutelsat W3 satellite for Ku bandwidth, is provided with Ka transponders (H transponders) for European coverage in cross-strapping with Ku transponders (J transponders) covering the south of Africa area.

Ka Satellite Coverage of W3A
The specified satellite network, which the Ka Uplink in Turin will operate with, will utilize for transmission from Europe to South of Africa the transponder H (operating in the Ka band from 27.50 GHz to 28.60 GHz in up-link from Europe and in Ku band from 12.50 GHz to 12.75 GHz in down-link to South of Africa) and for reception from South of Africa to Europe the transponder J (operating in the Ka band from 21.40 GHz to 21.65 GHz in down-link to Europe and in Ku band from 14,00 GHz to 14,25 GHz in up-link from South of Africa).

The Eutelsat W3A Ka band coverage on Europe is shown in Figure 1 and Figure 2 respectively for uplink and downlink. The Ku band coverage on South of Africa is shown in Figure 3. The W3A Frequency Plan is shown in Figure 4.

The Ka band Earth Station in Turin will operate on the following frequency bands:

a. Ka band Up-Link: 27.50 to 28.60 GHz;
b. Ka band Down-Link: 21.40 to 21.65 GHz.

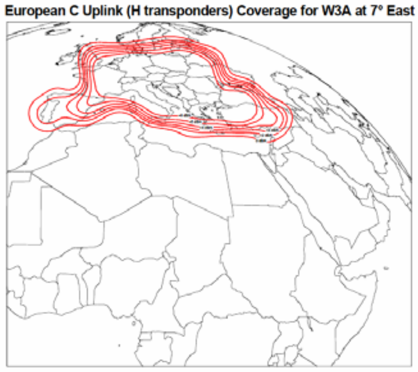

Figure 1 Europe C uplink coverage

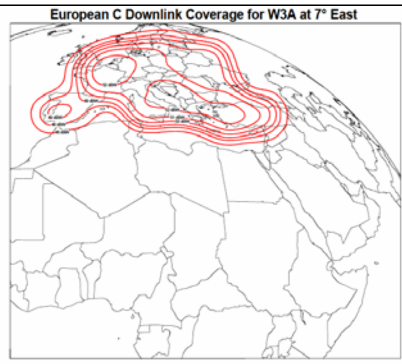

Figure 2 Europe C downlink coverage

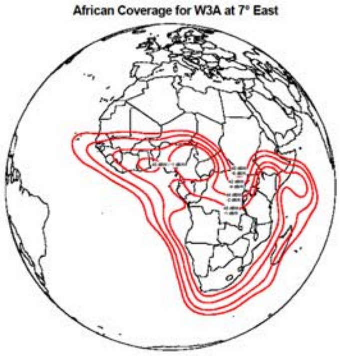

Figure 3 South of Africa UL/DL coverage

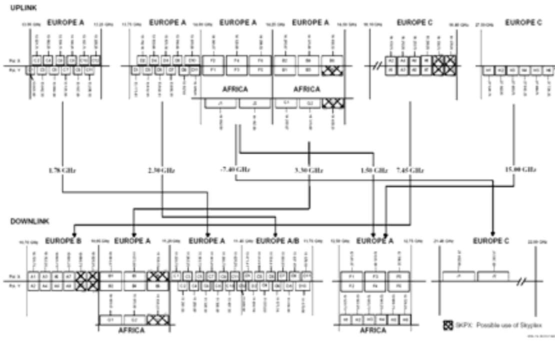

Figure 4 W3A Frequency Plan

Earth Station Design

The Earth Station Hub will be able to transmit, in the Ka Tx band operating on W3A satellite, digital DVB Data carriers generated by QPSK modulators in the L band (950 -1750 MHz) and to receive digital RCS carriers from remote stations, in Ka Rx band on W3A satellite, down converting these in the receive L band at the demodulator input. The IFL cables runs between Shelter and Indoor Room.

The Earth Station in the baseline configuration will be able to transmit up to three carriers with TWTA equipped with Linearizers. The Block Diagram is shown in Figure 5.

As shown in the blocks diagram, the Tx configuration has been conceived with maximum 4 digital signals to be combined in L band in order to have an input spare in addition to the three which can be up converted and transmitted by the Earth Station. The redundancy configuration is 1+1 either for Block Up Converters and TWTA subsystems in order to increase the earth station flexibility and availability during equipment failures.

The TWTA will be able to transmit up to 210 W (rated power) with TWT's of 250 W. This configuration allows the transmission of three simultaneous carriers each one with an EIRP of 74 dBW saturating the relevant transponders. In this manner the provided Earth Station EIRP capability is 82,91 dBW.

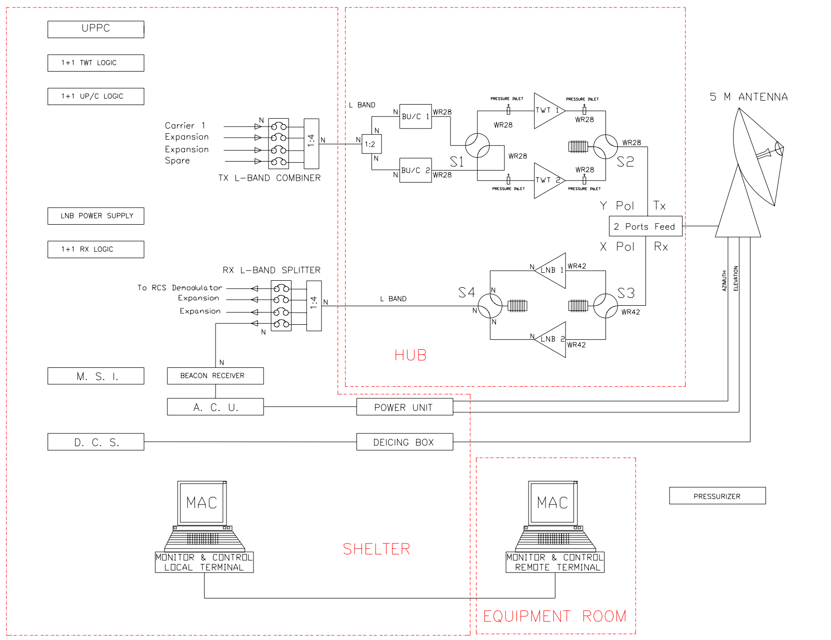

Figure 5 Earth Station Block Diagram

As far as the Rx configuration, the Low Noise Block Down Converters subsystem have a redundancy configuration of 1+1 in order to increase the earth station flexibility and availability during equipment failures in the same manner of Tx section. The down converted L band signal, obtained at the output of the redundancy D/C coax switch, will be fed to a 4 way splitter which will provide the connection with 3 L band cables to the RCS Demodulators Subsystems and to the Tracking Down Converter/Beacon Receiver for antenna automatic tracking carried out by the ACU (Antenna Control Unit). The ACU, operating with Step Tracking System algorithm, will drive the antenna motors after having com pared the received signals from Beacon Receiver with the data coming from Antenna Encoders.

The proposed Ka antenna is Cassegrain with 5m Reflector. The Feed is a two port Ka band feed provided with a Pressurizer in order to eliminate the possible harmful effects of dampness. The Antenna will be provided with the Hot Air De-Icing.

A 20 dB's UPPC system will compensate in transmission the effects of severe fading in Ka band in case of rains and atmospheric attenuations.

The Ka Uplink Earth Station can be subdivided in two sections:

- Antenna Section
- Shelter Section

The Antenna Section will host all the RF equipment, as follows:

- Antenna and Feed

- Feed Pressurizer
- Antenna Motors
- Antenna Encoders
- TWTA subsystems
- U/C subsystem
- LNBDC subsystem
- TX and RX redundancy switches

The Shelter Section will host all the Control equipment, as follows:

- TWTA Redundancy Control Panel
- U/C Redundancy Control Panel
- LNBDC Redundancy Control Panel
- UPPC Control Panel
- Monitor and Control subsystem
- 4 Way L band Combiner
- 4 Way L band Splitter
- Tracking Down Converter and Beacon Receiver
- Antenna Control Unit
- De-Icing Control Panel
- Short Break Panel
- No Break Panel
- UPS 50 KVA subsystem

In the Shelter the UPS and Short-Break/No-Break Panels have been shielded by the Electronic Equipment.

Design Analyses

Design analyses have been carried out to validate the Earth Station Design and performances, particularly in respect of the following parameters:

EIRP capability:	82,91 dBW
Antenna Gain:	60,95 dB's
TWTA for 3 Carrier Operation:	210 W rated power

Intermodulation. The results of the IM analyses provided compliance for two carrier operation as far as the IM power required for 4 KHZ and 12,5 MHz while for the three carrier operation the IM power required for 12,5 MHz was exceeded.

Link Budget. The calculations have been carried out under the following hypothesis:

a) Earth Station installed in Turin;
b) Remote Station (not object of the proposal) in a town of Kenya (Mombassa) covered by the W3A satellite (1,8m and 2W SSPA);
c) Transmitted Bit Rate by the Earth Station: 36 Mbps with FEC 2/3 and RS (29.5 Msps);
d) Transmitted Bit Rate by the Remote Station: 384 Kbps with FEC 2/3 and RS (315 Ksps);
e) Saturation Flux Density – (80 + G/T) = -86 dBW/m2;

f) Transponder Attenuator set at 3 dB;
g) Earth Station TWTA Out Back Off (OBO) at 4.15 dB's for three carrier transmission.

The link budget calculations have been performed in two directions: Turin – Mombassa and vice versa. The results provided a BER better than 10E-7 for the 99,90% of the time.

Implementation Project

Antenna

The 5m antenna, shown in Figure 6 and Figure 7 **5m Ka Antenna Pictures during Integration and Tests**

, is a conventional elevation over azimuth that allows a motion of ±30° motorized and from 0° to 360° manual, in azimuth, and from +5° to +80° in elevation. This motion capacity is obtained by means of a double motorization without the necessity of mechanical reconfiguration of the structure.

The antenna is provided with Azimuth and Elevation indicators. Limit and pre-limit Switches are included for the mechanical limits for the Azimuth and Elevation axes. A protected zone is obtained near the centre of the main reflector to allow the installation of the LNBDC and HPA subsystems.

The antenna is provided with lightning protection, adequate connection to independent ground from the grounding system of the same antenna, de-icing system on the reflectors and on the feed.

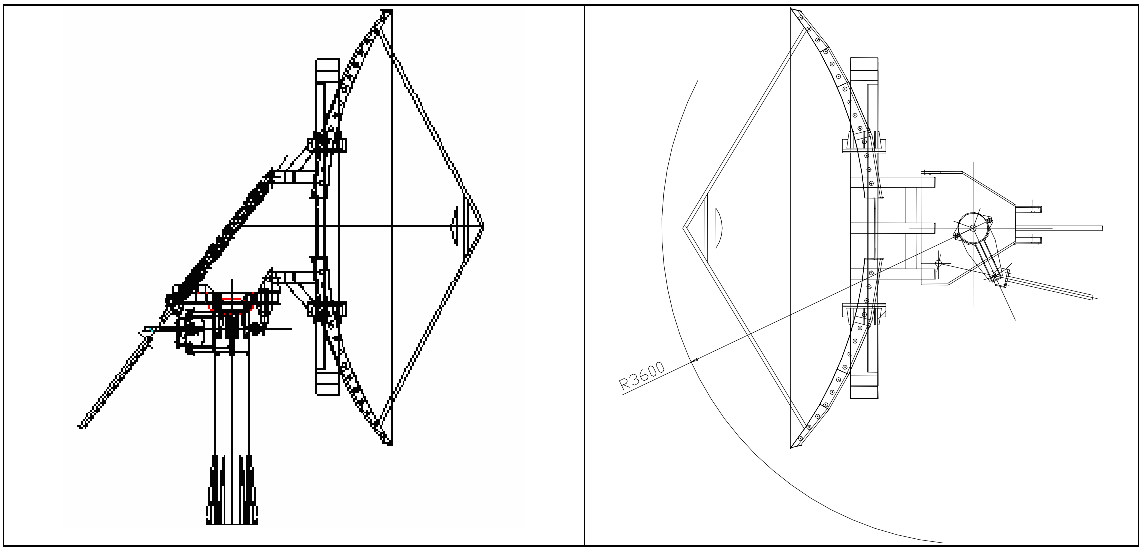

Figure 6 5m Ka Antenna Layout

The electrical performances of the antenna are shown in Table 1 while the Radiation Diagrams are shown in Figure 8.

Figure 7 5m Ka Antenna Pictures during Integration and Tests

Parameter	Value
❖ Reflector diameter	5 mt
❖ Polarization	dual linear (2 port feed)
❖ Frequency	21.40 - 21.65 GHz (RX Ka)
	27.50 - 28.60 GHz (TX Ka)
❖ Gain	RX: 58.81 dBi typical (@ 21.5 GHz)
	TX: 61.10 dBi typical (@ 28.0 GHz)
❖ Antenna Noise Temperature	83.15 K @ 38.1° elevation
❖ G/T	≥ 32.5 dB/°K @ 38.1° elevation
❖ TX/RX Sidelobes	Compliant with EUTELSAT ESS400 for Ka band
❖ XPD a –1 dB di contour plot	27 dB min.
❖ Insertion loss	0.4 dB max (TX)
	0.4 dB max (RX)
❖ Return Loss	21 dB min. (TX)
	20 dB min. (RX)
❖ Port Isolation	TX/RX 80 dB min (in TX band)
	TX/RX 70 dB min (in RX band)
❖ Power Handling	500 W CW for TX port
❖ Total loss between TWTA and Horn flange	1.67 dB

Table 1 5m Ka Antenna Main Performances

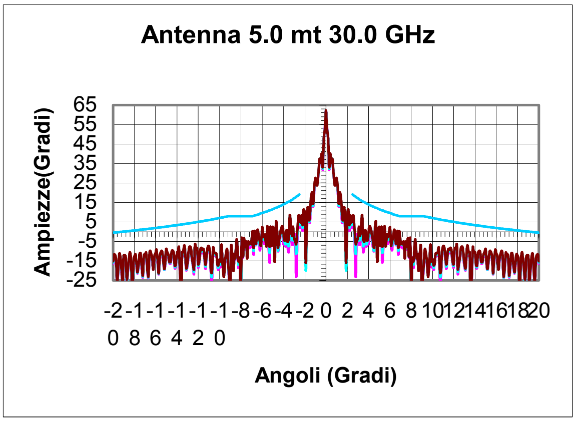

Figure 8 5m Ka Antenna Radiation Tx Diagrams

Measurements and Results of the Antenna rms

In order to assure the correct antenna assembly and, consequently, the good radiofrequency performances of the antenna it is necessary to verify that all the panel elements are placed in the correct position with respect to a reference coordinate system with a revolution axis coincident with the feed and sub-reflector axis.
Furthermore, in order to be sure that the correct assembly is obtained in the operational configuration of the antenna, the verification is made after the mounting of the reflector on the relevant pedestal.
This verification is accomplished by using a specific procedure that has the scope to check if the RMS value of the surface irregularities are within the maximum value limit (0.3 mm) defined in the design of the antenna in order to guarantee the specified gain of the antenna.
The procedure is accomplished with the following formula to calculate the deviation between the theoretical and the measured geometry using the following formula:

$$\left(\frac{\sin(\theta - \theta_m)}{\sin(\theta)} \cdot d \right)$$

Where:

θ is the theoretical angle of the point (see Figure 10);
θ_m is the read angle value;
d is the distance from the theodolite to the target (see Figure 10);

Some results of the RMS surface irregularities verification executed on 10th July 2004 at the installation site are shown in Figure 9.
The results show a very good value of 0.298 mm that is within the required value of 0.3 mm.

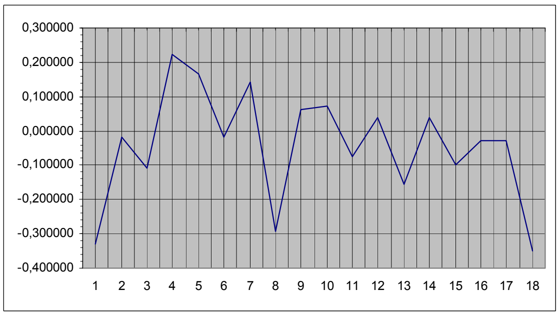

Figure 9 Sample of the RMS surface irregularities verification results

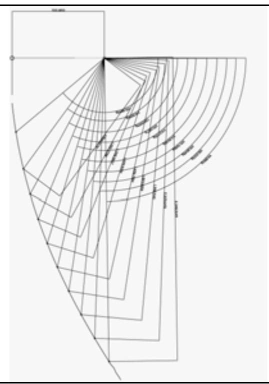

Figure 10 Theoretical angle and distance from the theodolite to the target

Another important aspect of the antenna design and realisation is related to the Ka band 2 port feed. The measured performances of the realised feed are better than the specified values in terms of Insertion loss (see **Errore. L'origine riferimento non è stata trovata.**), return loss (see Figure 12) and RX/TX Isolation (see Figure 13).

The radiation patterns of the feed in RX and TX polarization are, respectively, shown in Figure 14 and Figure 15.

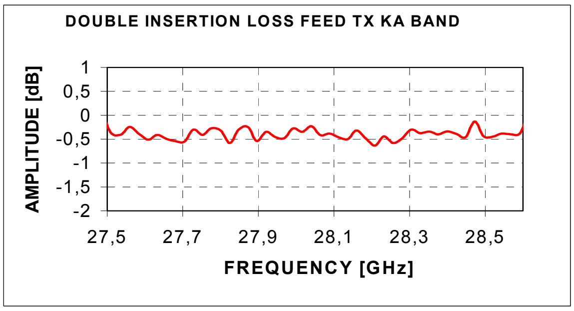

Figure 11 Insertion loss of feed in TX band

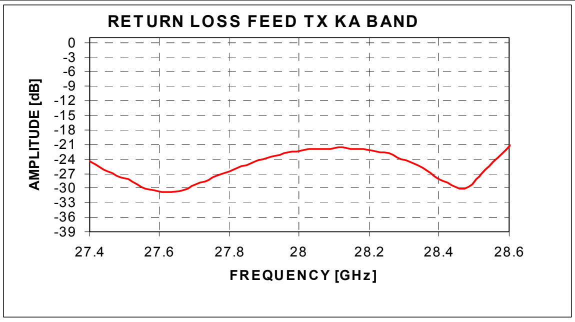

Figure 12 Return loss of feed in TX band

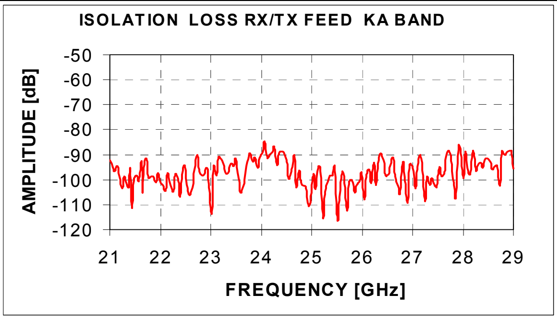

Figure 13 RX/TX Isolation of feed

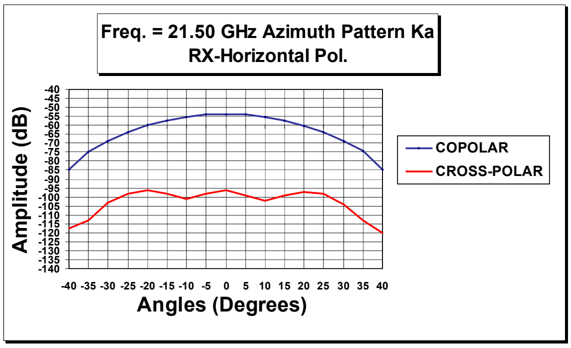

Figure 14 RX horizontal polarization feed pattern

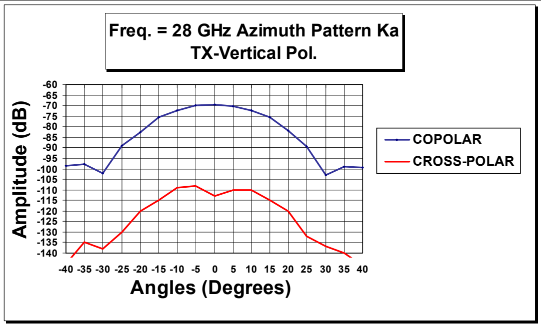

Figure 15 TX vertical polarization feed pattern

RX Subsystem

The Rx Equipment subsystem is essentially composed by the two LNB's in redundant configuration 1:1, which supply the down converted signals in L band to the 4 way splitter for the demodulator chains (not subject of this proposal) and for the tracking chain. The Rx subsystem block diagram is shown in Figure 16.

Low Noise Block DC subsystem characteristics

The Low Noise Block DC subsystem is composed by two LNBDC assembled in a redundant 1+1 configuration and controlled via the M&C subsystem installed inside the shelter.

Beacon Receiver

The Beacon Receiver has been designed for the reception and measurement of the Beacon signals transmitted by the known commercial satellites.

It particularly suited for the tracking System of Satellite Earth Station equipped with large diameter antenna that needs an optimum alignment to the satellite direction in order to maintain a very stable signal level at satellite input.

The Beacon Receiver has an L band input operating from 950 to 1950 MHz. The input signal is frequency converted by mean of a 10 kHz step synthesized down converter. A level detector circuit follows the down converter.

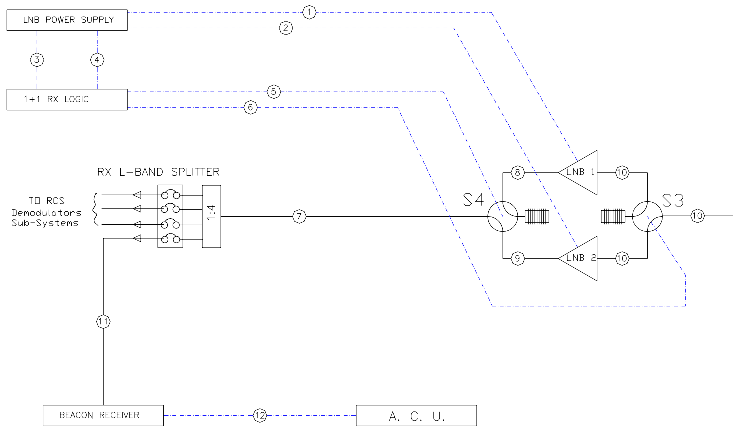

Figure 16 - Rx Equipment Subsystem

TX Subsystem

The TX Equipment subsystem is constituted essentially by the Block Up-Converter s/s and TWTA s/s, both in redundant configuration 1:1. The 4 way combiner supply the L band signal to the U/C redundant 1:1 subsystem input. The Tx subsystem block diagram is shown in Figure 17.

Block Up Converter redundant assembly

The U/C s/s (Miteq) is constituted by two U/C's and by the Switch Over Unit for outdoor installation.

High Power Amplifier

The TWTA Redundant 1:1 systems specified herein can consist of the components listed in Table 2. In addition to the above, the necessary wave-guide connecting circuitry, input RF circuitry, mounting hardware and necessary interface cabling is provided.

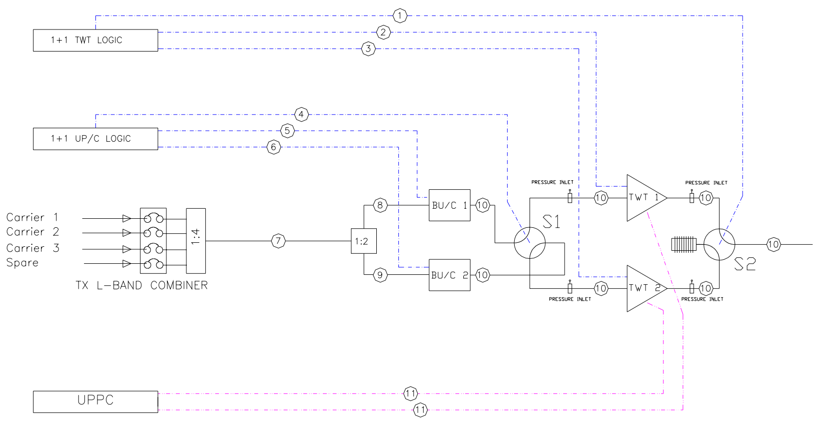

Figure 17 - Tx Equipment Subsystem

Component	Model	Qty
REDUNDANCY LOGIC	LGC0009A	1
TWTAs	MT3300	2
LINEARIZERS	-	2
RF SWITCHING NETWORK		1

Table 2 TWTA Redundant System Components

THE MT3300 antenna mount TWT amplifier is available for applications in Ka-Band up to 250 watts. This weather resistant amplifier is a compact, rugged power amplifier designed for extremely reliable operation. Always keeping our customers' needs in mind, MCL has designed the MT3300 to be easily integrated in both new and existing outdoor amplifier installations.
Incorporating the latest technologies, MCL provides a robust and efficient thermal design. Moreover, the MT3300's innovative high voltage power supply results in an extremely efficient, stable and low noise power system. To compliment the high voltage power supply, MCL has incorporated a new digital M & C system internal to the HPA to allow customers a higher level of system monitoring and control. Easy access to these new monitoring and control capabilities can be achieved by available RS485/RS232 interfaces or through the use of a portable handheld device.

UPPC

The UPPC allows the setting of the output power of the TWTA based on the received signal (beacon level) in order to compensate the link attenuation. Furthermore, it allows to remotely control the TWTA by setting the operational parameters of the amplifier.

Shelter

The Shelter will host the Antenna Tracking System, the UPPC Control System, the M&C System, all the Equipment Control Panels and the UPS/Power Supply System. The shelter plant layout is shown in Figure 18. As shown in this figure the Equipment area is shielded by the UPS/Power Supply area. A shelter side view is shown in Figure 19.

The shelter is air conditioned with air conditioned system "AERMEC" mod.CXM 0707 DUAL SPLIT, only cold, with remote control. The spilts mod. EXW 070 are positioned at wall, one for room, while the external unit is positioned on side C by means of appropriate support in 304 steel AISI.

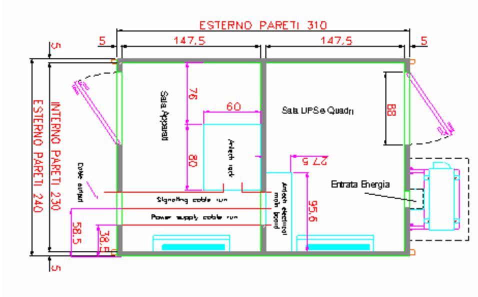

Figure 18 Shelter Plant Layout

Figure 19 Shelter Side View

Base Structure

The base structure in tubular is completely knit in reticular way, perimeter walls are in galvanized sheet 20/10. All the structure is painted first with protecting treatment Wash-Primer and after with white/gray poliuretanic bi component varnish.

The roof is flat and is realized in galvanized sheet dpt.20/10. On the approach part between roof and walls rafters in tubular are inserted to reinforce, isolated with panels in polyurethane with template in shaped sheet prepainted white gray dpt.10.10. The roof is covered with sandwich panels dpt mm 50+40=90, white/gray prepainted on the two sides that have packings of held along all the perimeter of the roof. The roof isolation is obtained by means of injection of polyurethanic resin between the two sheet supports.

The pavement is realized with multi layer panels of mm.25, type Chilean Pine covered with floor tiles in linoleum, spread in work with appropriate adhesive and in the part turned towards the ground covered with prepainted anticondenses sheet dpt.6/10.

The perimetral walls and the inside divisory are realised with type sandwich panels dp 50mm covered inner and externally with with/grey microrib sheet dpt 6/10, coibented with expanded polyurethane auto extinguishing Kcal/mtq x h°C = 0,44 and density approximately of 40 Kg/mc.

Shelter Dimensions

- The shelter has the following dimension:
- length: mt.2,40
- width: mt.3,10
- useful height: mt.2,10
- maximum height: mt.2,40
- Total Area mtq.7,44

Monitor and Control System

The M&C, shown in Figure 20 and Figure 21, is the system devoted for the acquisition/monitoring of all the equipment and subsystem components. It is installed on an industrial PC positioned in the rack and allows the monitoring of the system status, the automatic switching logics for the equipment, and allows the manual switching in case of fault for test and maintenance activities.

N° 2 Ethernet socket type RJ45 are equipped, one inside the Shelter near the control panel rack and the other one inside the equipment room (Skylogic area) where will be installed the remote PC controller.

The M&C can also check and monitor the following alarms, dry contact normally close, that open in alarm condition:

- detection of RF limit emission exceeding 40V/m (optional monitoring device);
- detection of RF limit emission exceeding 6V/m (optional monitoring device);
- Conditioning system;
- UPS system.

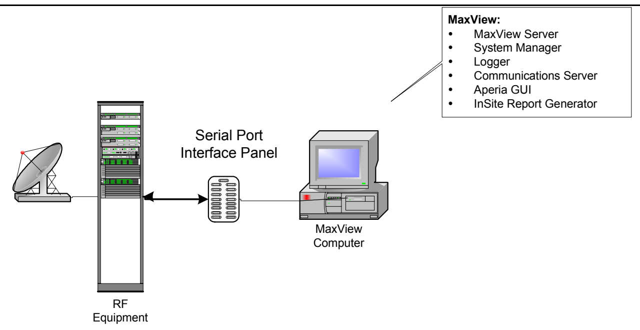

Figure 20 M&C System Architecture

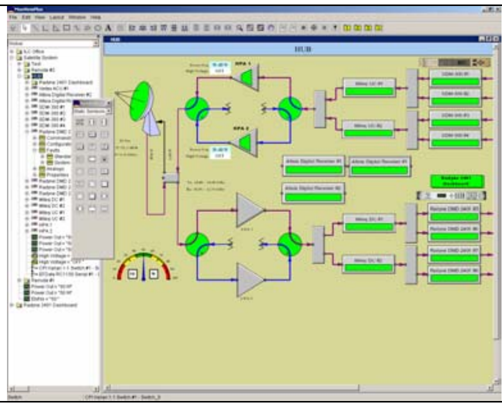

Figure 21 Sample window of M&C System

Ka Uplink Power Consumption

The Ka Uplink Power Consumption budget, both for break and no break, is shown in Table 3.

Items	No Break	Short Break
Total Power Consumption	**4.000,00**	**24.000,00**

Table 3 Ka Earth Station Power Consumption

Conclusion

The Ka Uplink Earth Station realized by Aersat for Skylogic is the first example in Europe for operational services completely in Ka bandwidth, making use of DVB RCS technologies. Cross-trapping techniques on the spacecraft will allow the interconnection between Europe and South Africa.

Its design, described in this paper, is based on a 5m Antenna with step track and on most advanced RF technologies in Ka Band, using very compact devices like Block Up Converters, Low Noise Block Down Converters and HPA's with very good performances. Rugged solutions have been adopted for the RF equipment which are mounted in outdoor and assembled inside the antenna hub, allowing waveguide connections to feed system with low losses. The configuration with full chain redundancy and the use of UPS guarantee a high availability of the Earth Station.

The completion of qualification and ESVA tests is scheduled by the first week of August 2004.