Ground Station Weilheim

DLR

Ground Station Weilheim

The DLR ground station in Weilheim, 60 kilometers south-west of Munich, was established in 1969 (start of construction November 1967). The data exchange with the spacecraft takes place via a variety of different antennas (ranging from 11 to 30 meters in diameter). The satellite ground station in Weilheim is operated by the DLR German Space Operations Center (GSOC).

According to the Consultative Committee for Space Data Systems (CCSDS), Weilheim is classified both as a Deep Space Network and a Non-Deep Space Network (Near Earth Network) and can support space missions in the L, S, X, Ku and Ka frequency bands.

The individual antenna stations at Weilheim can be operated independently – which means that the Weilheim ground station can support several missions simultaneously (multi-mission operation). All antennas and station facilities are monitored and controlled from one common control room. New software developed at GSOC allows the necessary sequences to be standardized, regardless of the particular mission, frequency range and orbit type, which considerably simplifies the operation.

Inauguration: 1968
Operation: 24 hours, 7 days a week

Antennas

- S67 - 15m - S-Band
- S68 - 30m - L/X-Band
- S69 - 15m - S-Band
- S70 - 11m - Ku-Band
- S73 - 13m - Ka-Band

Services

- Mission Integration
- Engineering Support
- RF Compatibility Test
- LEOP Support
- Transfer Orbit Services Support (TOSS)
- In-Orbit Test (IOT)
- TT&C Services
- Emergency support

Point of Contact

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2. Antennas

The Weilheim Station complex provides communications with Earth orbiting, geostationary spacecrafts, and deep space probes. The antennas supporting Multi-Mission purposes are listed in the table 2-1. There are additional antennas on the site operated by DLR on behalf of external customers.

2.1 Antenna Overview

An overview of the antennas in Weilheim which are used for Multi-Mission operations is provided in table 2-1.

	Antenna				
Designation	13 m	30 m	15 m I	15 m II	11 m
GDS Name	S73	S68	S67	S69	S70
Band[(1)]	Ka	L, X	S	S	Ku
Frequency [GHz] (Receive)	18,1 - 21,2 25,5 - 27,5	N/A	2,2 - 2,3	2,2 - 2,3 **8,0 - 8,5**	10,70 - 12,75
Frequency [GHz] (Transmit)	22,55 - 23,15 27,5 - 31,0	N/A	2,025 - 2,12	2,025 - 2,12	13,75 - 14,50
3dB Beam width (Transmit) [deg]	0,056	0,35 (S-Band)	0,66	0,66	0,15
Gain [dBi] @ [GHz]	65,5 @ 20	54 @ 2,295	47,8 @ 2,25	48,3 @ 2,25	60,8 @ 12,75
G/T [dB/K] @ elevation [°]	42 @ 10	35 @ 5 (S-Band)	26,7 @ 5	27,8 @ 5	36,3 @ 10
Pointing Accuracy [deg]	±0,001	±0,001	±0,03	±0,03	±0,01
EIRP [dBW] @ [GHz]	90 @ 30	N/A	58..73 @ 2,075	59..79 @ 2,075	≤ 88,5 @ 14,25
Polarisation	RHC/LHC H/V	RHC	RHC/LHC	RHC/LHC	RHC/LHC H/V
Telemetry in Band	Ka	N/A	S	S	Ku
Command in Band	Ka	N/A	S	S	Ku
Tracking in Band	Ka	N/A	S	S	Ku
Tracking Speed AZ	15	1,5	15	15	2
[°/s] EL	6	1,0	6	6	2
Category[(2)]	A	A, B	A	A	A

Table 2-1 Weilheim antennas for Multi-Mission operations, (1) Designation according to IEEE classification, (2) A: near Earth network; B: deep space network; see definiton in § 3.1

2.2 Visibility

The geostationary visibility above 10° elevation is between -50° and +70° longitude (compare figure 2-1).

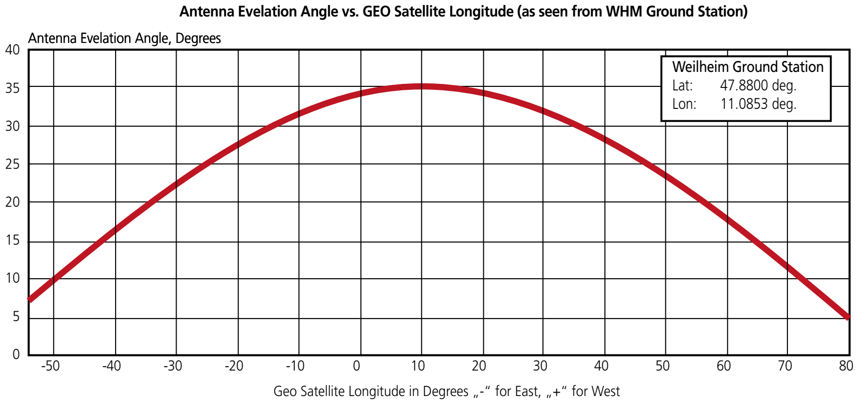


Fig. 2-1
Visibility for GEO satellites from Weilheim Ground Station

2.3 Horizon Mask

Each antenna has a unique horizon mask.
This is shown in the figure 2-2 for each antenna.

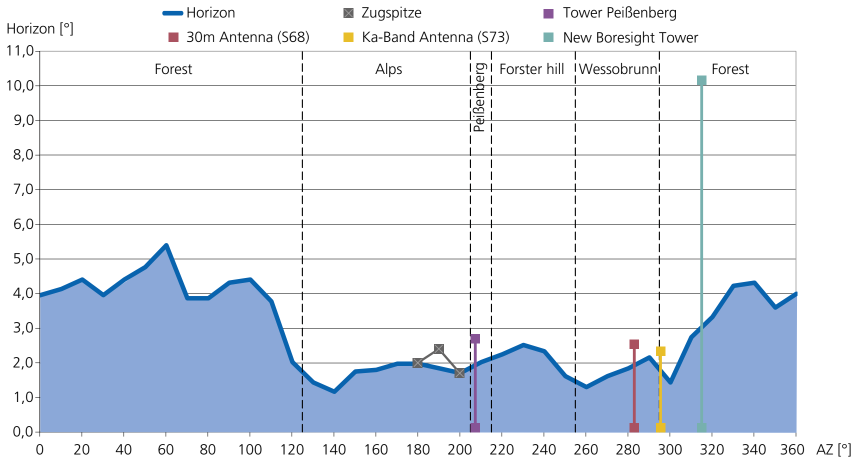
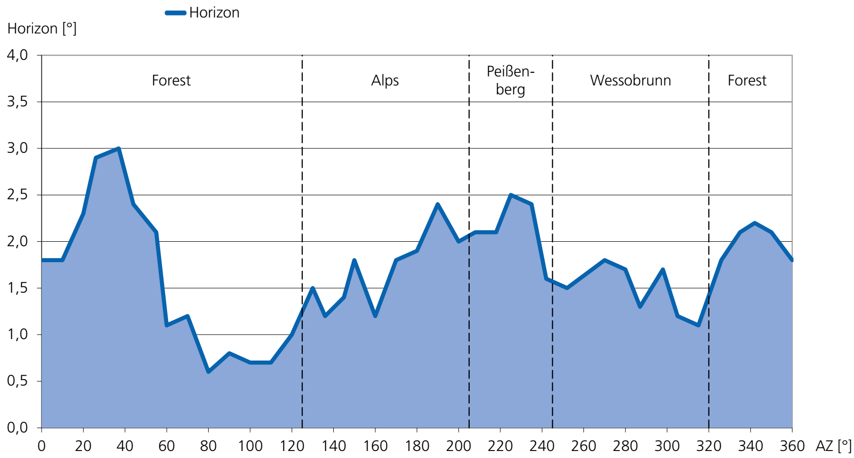
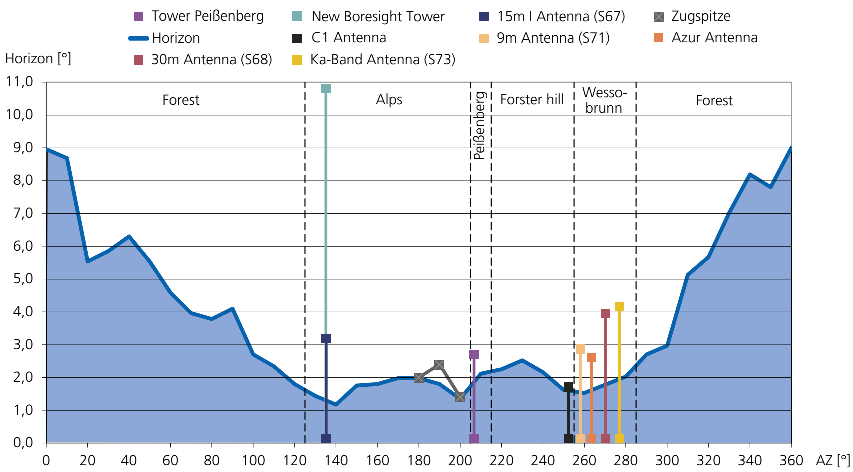


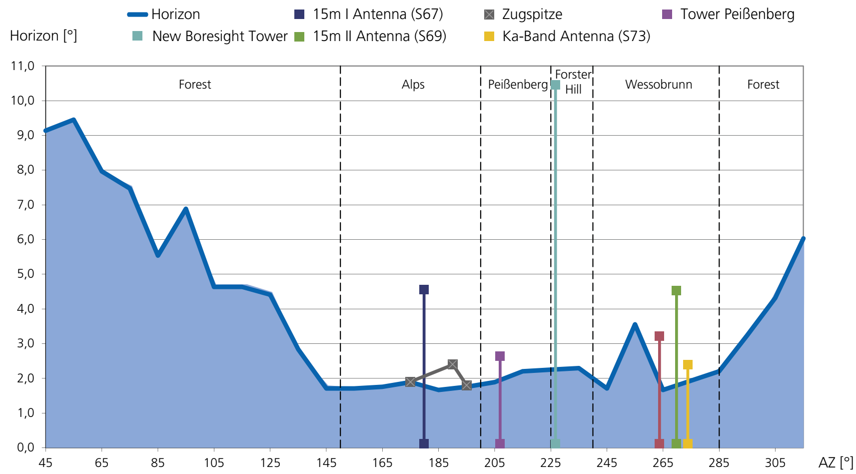
Table 2-2
a) Horizon mask - 15 m I antenna (S67)



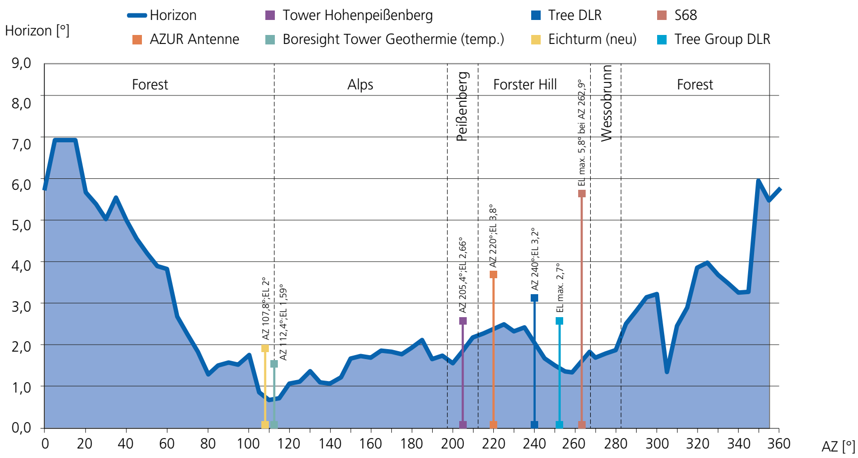
b) Horizon mask - 30 m antenna (S68)



c) Horizon mask - 15m II antenna (S69)




d) Horizon mask - Ku-Band antenna (S70)




e) Horizon mask - Ka-Band antenna (S73)

3. Subsystems

3.1 Ground Station Subsystems Overview

The Weilheim Ground Station concept is depicted in the figure 3-1.

The station concept is to use as far as possible standard base-band equipment for the different antennas and applications. This concept has been realized by building up a pool of TT&C base-band units, which can be connected to the different antenna- and RF-systems by means of switch matrix. This solution allows flexible and cost-effective usage of equipment in conjunction with a high grade of redundancy. Furthermore, it allows the support of special requirements (e.g. multiple TM channel processing or extremely high availability requirements) by job-splitting on multiple devices.

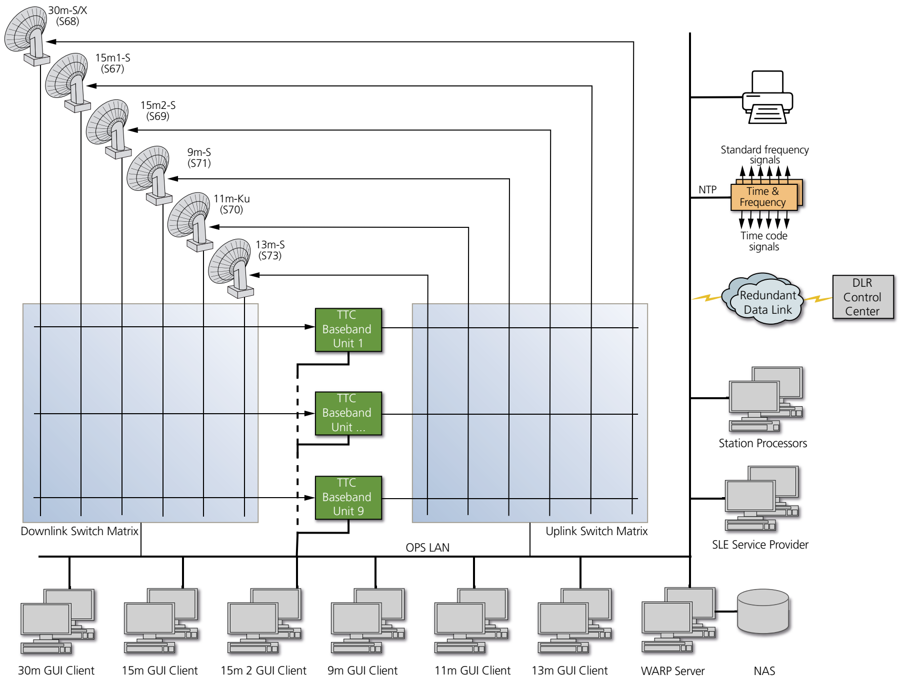


Fig. 3-1 Weilheim Ground Station concept

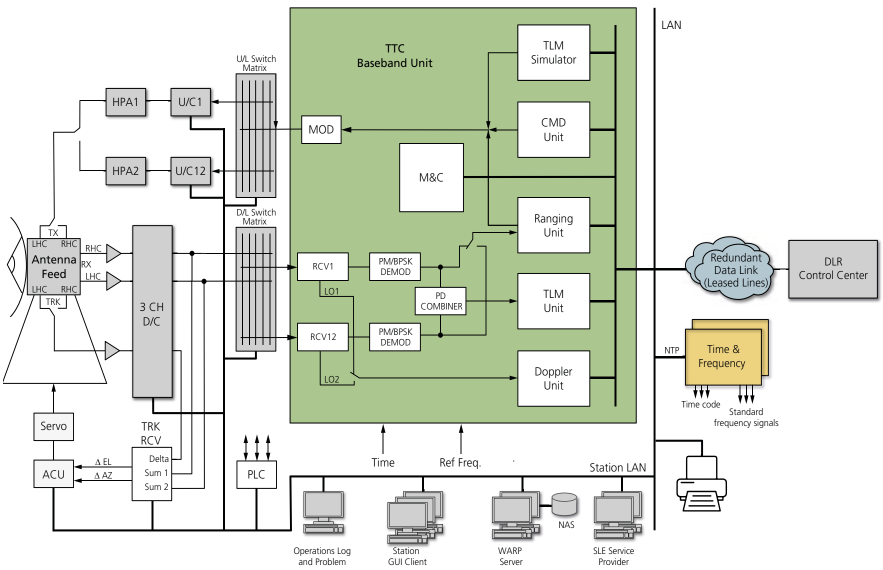


Fig. 3-2 Block diagram of a Ground Station antenna (15 m S-Band)

3.2 Base-Band Subsystem

The overall station IF-Base-band system consists of several identical CORTEX systems, which are cross-switched to the different station systems and configured in references to the actual satellite missions, see figure 3-3 (CORTEX is a registered trademark of the former Zodiac Data Systems, now Safran Data Systems).

Most functions are performed digitally, either by standard microprocessors or DSPs or by means of dedicated digital components (synchronisation, coding). The following functions and signal processing performances are listed:

- IF reception
- Telemetry processing
- IF modulation / demodulation
- Doppler measurement
- Satellite ranging
- Satellite telecommanding
- Telemetry simulation
- Time code decoding and data time-tagging
- Reference frequency
- Coding and synchronisation

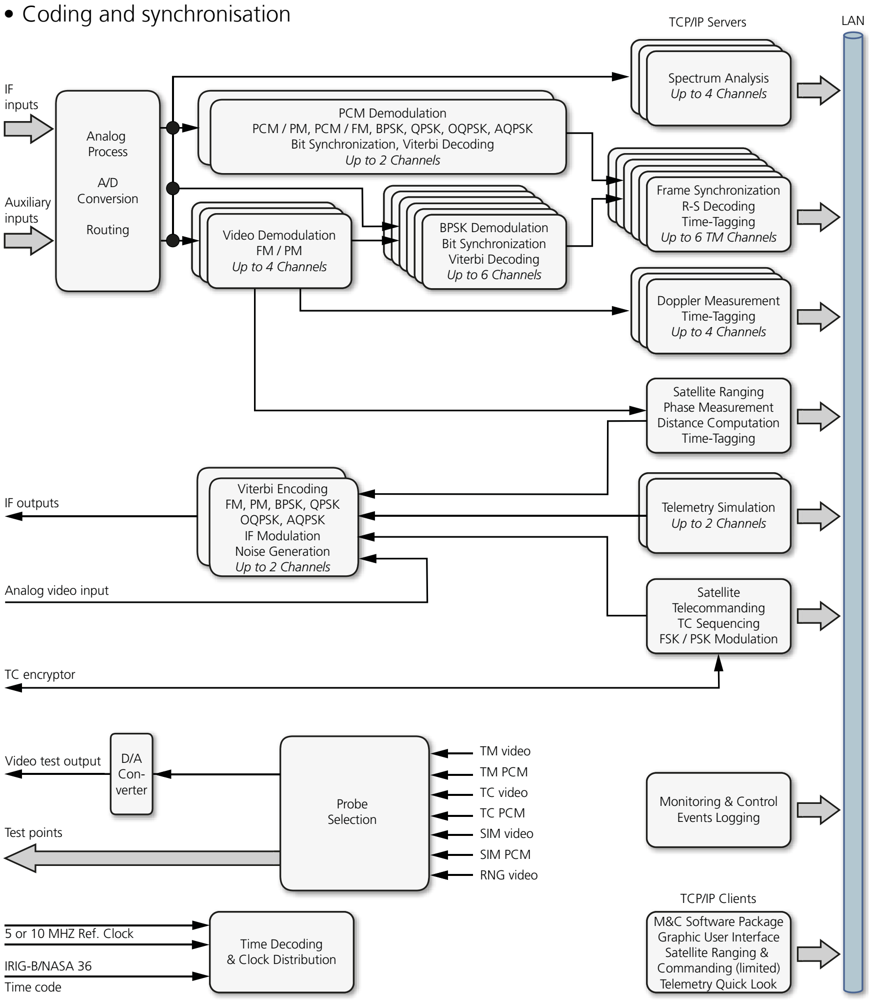


Fig. 3-3 Functional block diagram of the IF-Base band unit (Cortex CRT Quantum)

3.3 Monitoring and Control Subsystem

3.3.1 Antenna Monitoring and Control

The M&C system "WARP10" handles all monitoring, commanding and processes applicable to the antenna, the ground procedures for using it and the data products that are taken as input or generated by it.

WARP10 is built from different applications that manage antenna configuration, status control and visualization, and the control of workflow execution activities (see figure 3-4).

The system is comprised of the following components:
- A Parameter Database (PDB) as central component to disseminate parameter based data between all WARP10 components and includes:
  - PDB repository to provide all parameter definitions
  - PDB server to disseminate parameters in real-time
  - PDB proxy applications to support data transfer between different PDB instances
- Different ‚Generators' to build the interface to the antenna devices
- Graphical User Interface (GUI) clients presenting all information to the user

An additional processor performing:
- Control of the configuration in a context specific form as e.g. the Configuration Observation Process (COP), level 3 and 4 processors, generating high level information out of device level data
- A resource manager to grant control to resources shared within the system

Workflow engines executing the predefined steps, i.e.:
- Setup an antenna for a specific mission, check if the settings are all mission compliant
- The handling of orbit prediction data, to process incoming predicts or two line Elements (TLE) into a format understood by the Antenna Control Unit (ACU)
- Or all steps necessary to provide real satellite support
- Logger utility to store all parameter changes for later investigations
- Tools
  - Log file analysis tool
  - Report generation
  - System administration

The software components are in most cases generic and configured for the use on a specific antenna system with configurations customized for an antenna. Only the interfaces to the antenna devices (‚generators') are in some cases antenna specific to provide an explicit service.

In addition to the WARP10 application environment a separate control instance called NEMO is used to start and stop the WARP10 instances, and to move instances between the hardware servers.

3.3.2 Satellite Monitoring and Control in MM-BSCC

The MM-BSCC will be equipped with the same software as already approved in GSOC-OP. For telemetry processing and visualization Satmon is used, for commanding SCOS-2000. A data access server is in place to host telemetry and AFD files. GSOC-OP AFD is used to transfer data from GSOC to MM-BSCC.

The equipment for the EDRS-BSCC is to be defined.

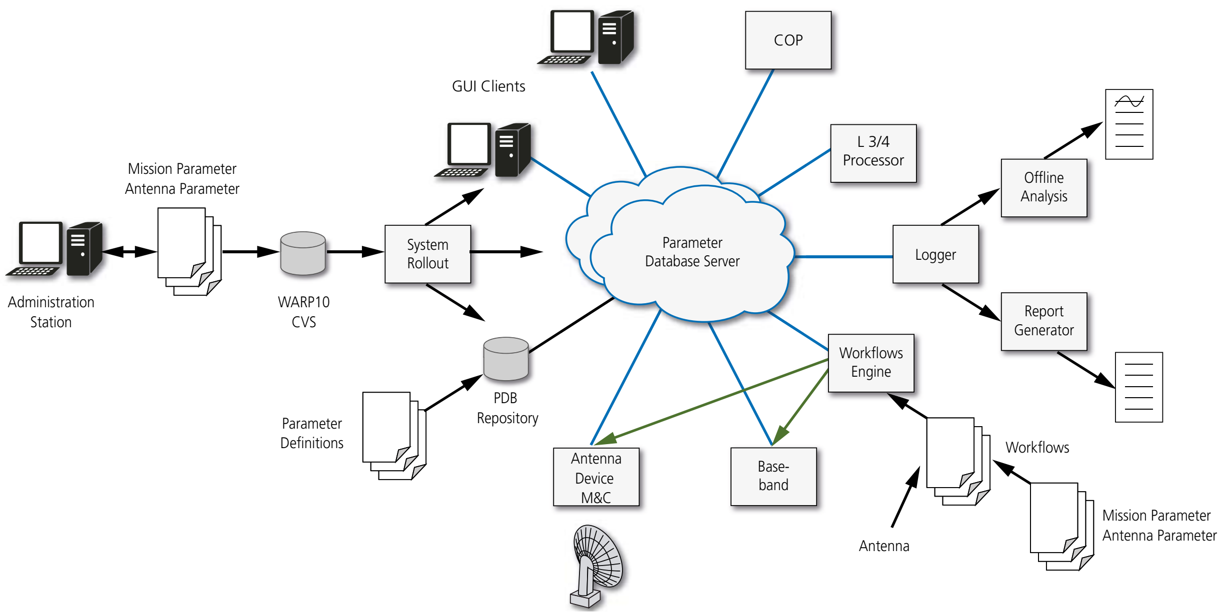


Fig. 3-4 WARP10 functional overview

3.4 Simulation and Test Facilities

The station test and calibration facilities fulfill two functions:

- Pre-pass routine operations, including routine calibration and tests
- Maintenance activities, including maintenance calibration and tests

A test up-converter, installed in each of the S-Band Antennas, connected to the CORTEX simulator, is used to generate the expected satellite signal. This is fed to the input of the LNA.
With this setup all downlink equipment can be checked functionally. BER measurement and receiver AGC calibration can also be done.

Test antennas are mounted on a 20 m tower at defined height. A remotely operated test up-converter, connected to the antennas, is used for auto-track phase adjustment and signal verification.

Future test capabilities are in development: Three ESA developed Portable Satellite Simulator (PSS) will be put into operation. A PSS system is capable of supporting the Data Flow Test (DFT) in parallel to normal operations, therefore, the reconfiguration of the CORTEX (from simulation to normal mode) is no longer necessary. Each PSS can simulate the data flow for one antenna. Having several PSSs it will be possible to simulate several data flows at the same time.

3.5 Data Storage and Archiving

As seen in figure 3-1 and figure 3-2 data storage devices for archiving of telemetry data are available for each Ground Station antenna. To have a central, highly available data storage, a redundant server system providing a large Net File System (NFS) data store and a data tape backup is installed. The NFS data store is built as RAID level 5 system and, therefore, tolerant to hard disk failures.

3.6 In-Orbit-Test Subsystem

The 13m Ka-band antenna in Weilheim has an in-orbit test system for the verification of the satellite payload in orbit. Customer specific measurements can be implemented by the team in Weilheim if required. With the help of the radiometer connected to the IOT software, a direct correction of the substantial atmospheric attenuation in the Ka-band is possible. If this attenuation wouldn´t be taken into account, it would represent the greatest measurement uncertainty in the overall system.

In orbit tests are performed with several devices accommodated on an "IOT-Bench":

- Spectrum Analyzer
- System Analyzer
- Synthesizers
- Power-Sensor
- etc.

Sample of IOT-Measurements	Stability Test
Antenna Pattern (Co-/X-Polar) - Step Hold - Slew - Various	
Antenna Cross-Polarization-Isolation	
Transponder EIRP	X
Transponder SFD	X
G/T	X
Transfer Curve	
Gain Step Deltas	
Transponder Linearity (C/3IM)	
Frequency Response	
Noise Shape	
Frequency Conversion	X
Phase Noise	
Beacon EIRP and frequency	X
Spurious / Beacon Spurious	
TBD – measurements on customer request	(X)

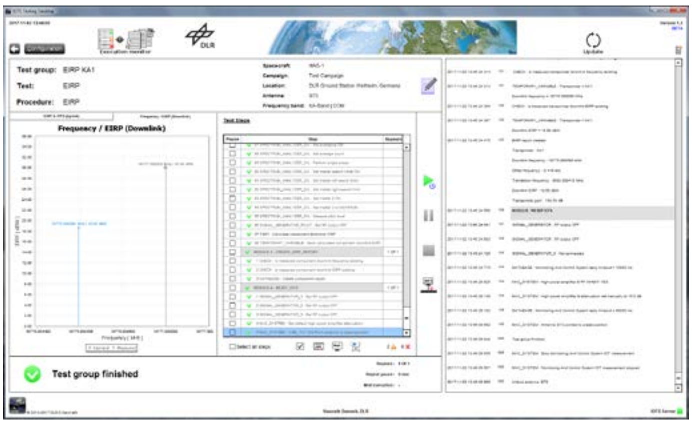


Fig. 3-5 Weilheim In-Orbit Test System GUI

4. Site & Buildings

4.1 Location

The Ground Station complex Weilheim is located about 60 km southwest of Munich and about 30 km south of Oberpfaffenhofen. The figure 4-1 shows the Weilheim premises indicating the buildings and antennas.

Site visits require a formal invitation, a valid passport or ID. For longer stays the visitor is registered on a list at the gate.

By car:
From Munich take the motorway A95 to Starnberg and then state road B2 to Weilheim. In Weilheim turn right in direction to Landsberg and follow the road for approx. 6.5 km. Then follow the DLR signs for approx. 2 km.

By train:
There is connection by train between Munich central station and Weilheim every 30 min. Travel time is 40 minutes From Weilheim city to the DLR Ground Station premises taxis are available (travel time about 10 minutes).

By taxi:
From Munich center or Munich Airport taxi expenses are more than 100 Euros.

Fig. 4-1 Weilheim Ground Station

4.2 Climate & Environmental Conditions

The pre-alpine area of South-Bavaria experiences considerable precipitation with varying snow falls in winter and variable rainfall levels throughout the year. Winds are usually low and do not exceed 100 km/h. Gusts do not exceed 160 km/h.

A summary of the weather characteristics for the Weilheim area is given in table 4-1.

Weilheim Weather Characteristics	
Warmest Month	July
Average Daily Medium Temperature for July	17°C
Highest Recorded Temperature in July	37°C
Lowest Recorded Temperature in July	2°C
Coldest Month	January
Average Daily Medium Temperature for January	-2°C
Highest Recorded Temperature in January	10°C
Lowest Recorded Temperature in January	-25°C
Average Annual Rainfall	1040 mm

Table 4-1 Weilheim weather characteristics

4.3 Environmental Conditions

Table 4-2 lists the environmental conditions which affect the operations of the installations.

	Operational Conditions	**Survival Conditions**
Outside Temperature	From -30°C to 50°C	From -35°C to +60°C
Inside Equipment	From 0°C to +40°C	N/A
Wind	≤ 75 km/h (gusts < 100 km/h)	≤ 200 km/h (antenna in survival position) < 150 km/h (antenna in operational position)
degraded Performance	≤ 120 km/h	N/A
Rain	100 mm/h	N/A
Snow	≤ 30 mm/h (heating system required)	≤ 100 mm/h max. 300 mm at 90 km/h wind
Ice (on not heated surfaces)	≤ 5 mm	≤ 30 mm at 90 km/h wind
Humidity	≤ 100 %	N/A
Solar Radiation	1 kW/m2	N/A
Seismic	N/A	0,3 g horizontal 0,1 g vertical

Table 4-2 Weilheim Ground Station environmental conditions

4.4 Uninterrupted Power Supply

All the power supply comes from the mains power grid. The mains electricity goes through the UPS (Uninterrupted Power Supply) block before being connected to equipment. The UPS facilitates in avoiding short-term power supply interruption that could lead later to troubles in equipment functionality. In case of long-term power break, there will be no problem to get enough electrical power inside of the station. A powerful diesel generator can produce at least 1.2 MW within 10 seconds, which is sufficient to drive every antenna in operational mode.

A summary of the electrical characteristics of Weilheim Ground Station is given in table 4-3. 139/05 will be also connected to the UPS.

Average Need in Electrical Power	400 kVA
UPS Capability	4 x 200 kVA
Diesel Generator	1,2 MW

Table 4-3
Electrical characteristics of Weilheim Ground station

4.5 Time and Frequency System

The Ground Station is equipped with an automatic redundancy switching Time and Frequency System comprising the following components:

- Reference generator with high performing GPS Receiver System
- Distribution units for time, pulse and frequency

The characteristics of the Time and Frequency System are provided in table 4-4, a sketch of the system is depicted in figure 4-2. The Ground Station Time Standards are synchronized to Universal Time Coordinate (UTC).

Time & Frequency Reference System (Master)	2 x TimeTech RefGen USO – Automatic redundancy switching – GPS input with 12 channel timing receiver – Internal OCXO
Time Code	IRIG-B
Pulse	1 pps
Reference Frequencies	5, 10 and 100 MHz, sine wave
Time Protocol	NTP
Timing Accuracy	< 40 ns rms (150 ns peak) to UTC(USNO)
Time & Frequency Control Computer	NTP server Monitoring and Control

Table 4-4 Weilheim time and frequency characteristics

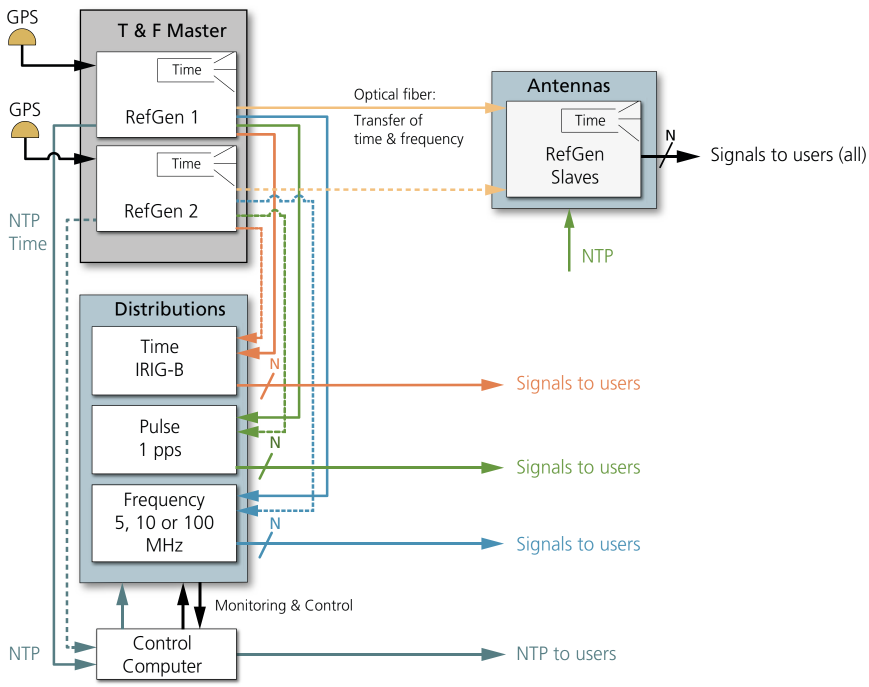


Fig. 4-2 Weilheim Time and Frequency System

The Reference Generator (RefGen):
- is equipped with an Ultra-Low Noise, Ultra Stable Oscillator for internal frequency generation,
- generates time code signals and standard frequency signals from the GPS reference.

Its front side has a one-inch high date and time display showing the day of the year (1 … 366) and the time (hours, minutes, seconds).

The RefGen Master provides time and frequency to local and distant distribution units. The RefGen specifications are provided in table 4-5. The reference signals are transferred:
- by coaxial cable to (local) slave units for time, pulse or frequency distribution,
- by fiber-optics to remote RefGen Slaves in distant antennas,
- over LAN for NTP to the central T&F control computer

The T&F control computer monitors and controls the whole T&F system. Its two internal NTP servers provide time synchronization to the GS computer network.

Oscillator Frequency	5 MHz
Frequency Stability 1 s 10 s 100 s 1,000 s 10,000 s	 6×10^{-14} 7×10^{-14} 3×10^{-13} 4×10^{-13} 1×10^{-12}
Phase Noise (@ 10 MHz) 1 Hz 10 Hz 100 Hz 1 kHz 10 kHz	 -128 dBc/Hz -144 dBc/Hz -150 dBc/Hz -151 dBc/Hz -151 dBc/Hz
Phase Noise (@ 100 MHz) 1 Hz 10 Hz 100 Hz 1 kHz 10 kHz	 -102 dBc/Hz -118 dBc/Hz -133 dBc/Hz -160 dBc/Hz -165 dBc/Hz
Aging	$\pm 5 \times 10^{-11}$ (± 50 ppt) per day

Table 4-5 Specification of the RefGen USO

4.6 Computer Network

All servers and network elements are interconnected to a switched 10/100/1000 Mbit Ethernet based Local Area Network (LAN). There are two physically separate LANs (Office LAN and OPS LAN). Identical managed switches are used for these interconnections. Devices and protocols in the OPS LAN are redundant. The equipment installed inside the antenna basements of each station is connected via fiber links to the LAN.
This means, that all subsystems of the antennas are accessible from the station computers to perform necessary monitoring & control functions.

Protocols used at the Weilheim Ground Station LAN are:
- TCP/IP
- NETBEUI (not for operations)

4.7 WSP-C (Weilheim SLE Provider)

The SLE services implemented in the WSP-C are:
- Return All Frames (RAF): TM as received from the Spacelink
- Return Channel Frames (RCF): TM separated in virtual channels
- Forward CLTU: TC send as CLTU (Communication Link Transmission Unit)

For details see [RD8] and [RD9].

Return Services are supported in 3 modes:
- Online complete: All TMs are delivered. During network congestion, TMs are queued and sent later.
- Online timely: TMs are delivered in real-time. During network congestion, TM are discarded at the provider side to maintain the real-time quality of the link.
- Offline: TMs are saved in a TM archive at the Ground Station and can be delivered offline to the SCC via FTP or played back through the SLE provider later.

Forward Services:
- All TCs are received in sequence by the SLE provider. TCs can be configured to be sent time tagged to the base-band equipment.

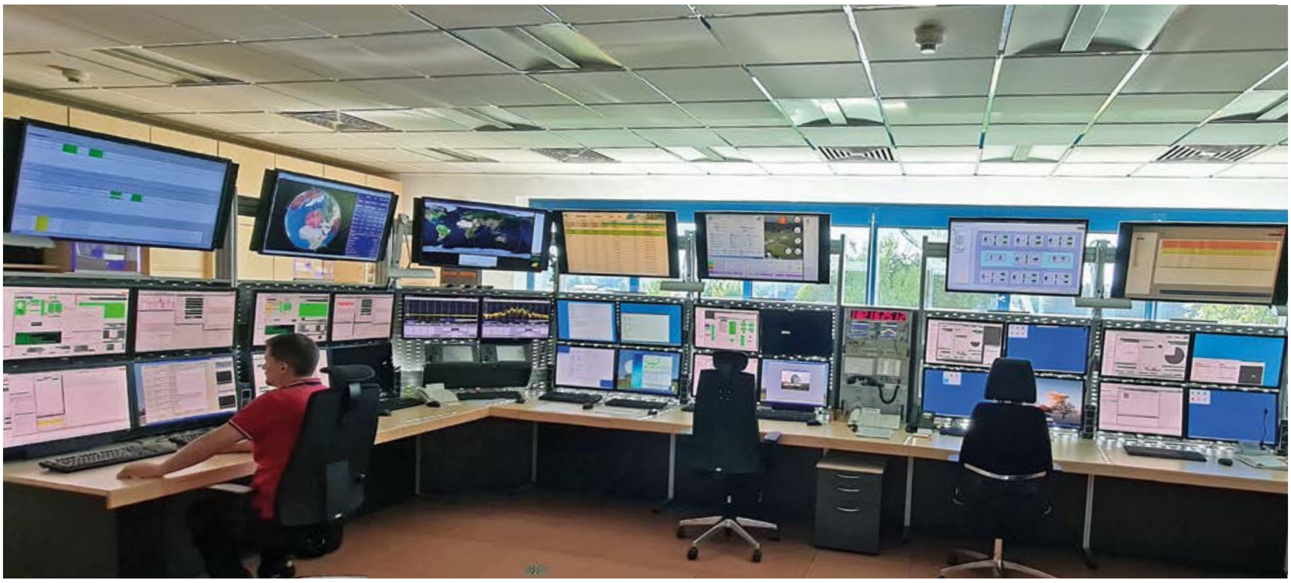


Fig. 4-3 Ground Station antenna control room

5. Services – Ground Station Support

5.1 Satellite Data Support

5.1.1 Telemetry and Telecommand Service

Weilheim ground station adopts the space link extension (SLE) standard, designed by the CCSDS community for Telemetry- and Telecommand-Data transfer between control center on the ground and the spacecraft. The SLE protocol is widely supported by many space agencies worldwide, following the same standard, Weilheim ground station is able to cooperate with different control centers and agencies for offering real-time mission support.

Online SLE Service

The software WSPC (Weilheim SLE Service Provider for Cortex) is designed and optimized to meet the specific requirement of the ground station Weilheim. The following SLE services are supported by WSPC:

- Forward Communications Link Transmission Unit (CLTU): To forward TC to the Cortex for the uplink. All TCs are received in sequence, and they can also be configured to be sent time-tagged to the baseband equipment.
- Return All Frames (RAF): To return all TM from a space link
- Return Channel Frames (RCF): To return TM for specific virtual channels from a space link

The return frame services are supported in 2 modes:

- Online Complete: All TM's are delivered. During network congestion, TM's are queued and sent later
- Online Timely: TM's are delivered in real-time. During network congestion TM are discarded at the provider side to maintain the real-time quality of the link.

WSPC is able to provide concurrent supports for multiple spacecrafts, and each spacecraft will have its own dedicated service sessions, identified by the service agreement. As Figure 5 1, shows, the service session can be seen as a container for the actual service instances. If uplink is required, a single spacecraft will then have two sessions – one "Forward Service Session" for the uplink service instance, and one "Return Service Session" for the downlink service instances.

Having an external M&C interface, WSPC is seamless integrated into the Weilheim Antenna M&C system, which allows the operator to configure SLE services for a spacecraft mission via Weilheim's central M&C system. Hence it greatly reduces the configuration time and makes a solid step towards the future station automation.

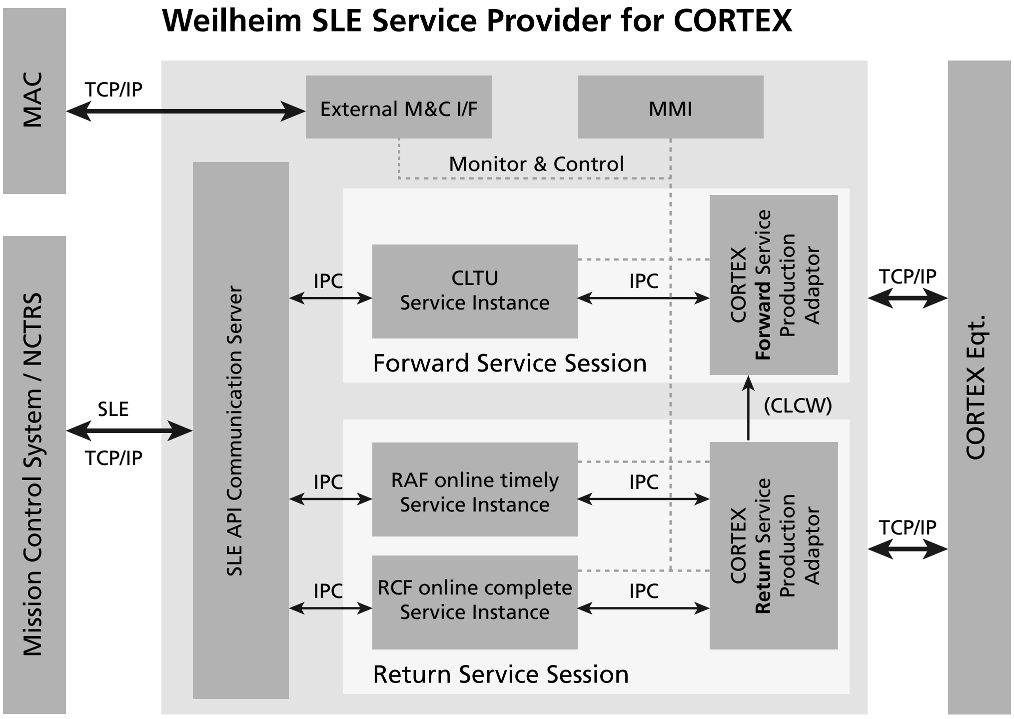


Fig. 5-1 Weilheim SLE Service Provider for Cortex

Offline SLE Service

Besides WSPC, Weilheim can also provide offline SLE services with the in-house developed software SOP (SLE Offline service Provider). As a complement to WSPC, SOP can provide SLE service when the space link is not available. It can be used to fill the TM gap due to the timely limitation of the online service, or to replay the TM in the case of possible data loss that might occur during online data transfer.

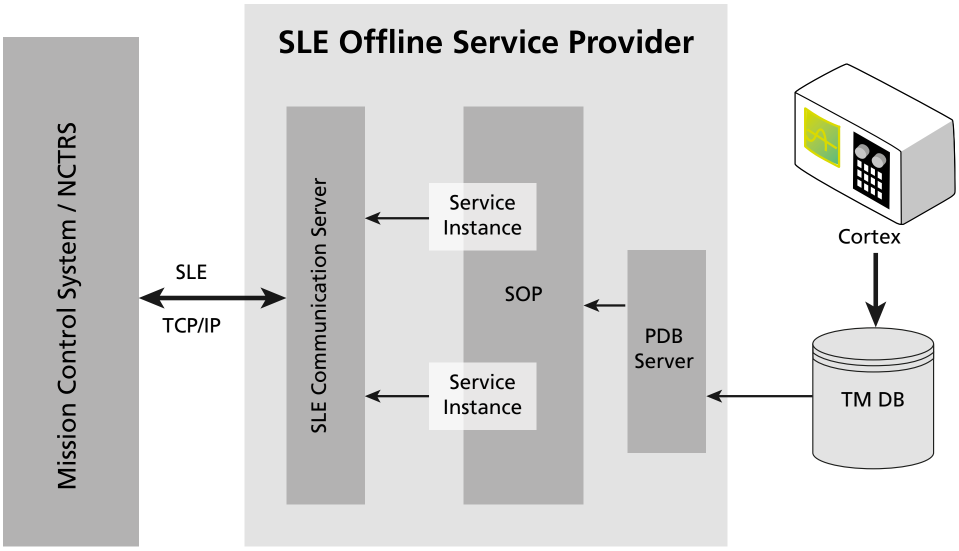


Fig. 5-2 SLE Offline Service Provider

The SLE services implemented in the WSP-C are:
• Return All Frames (RAF): TM as received from the Spacelink
• Return Channel Frames (RCF): TM separated in virtual channels
• Forward CLTU: TC send as CLTU (Communication Link Transmission Unit)

Return Services are supported in three modes:
• Online complete: All TM's are delivered. During network congestion, TM's are queued and sent later.
• Online timely: TM's are delivered in real-time. During network congestion, TM are discarded at the provider side to maintain the real-time quality of the link.
• Offline: TM's are saved in a TM archive at the ground station and can be delivered offline to the SCC via FTP or played back through the SLE provider later.

Forward Services:
• All TCs are received in sequence by the SLE provider. TCs can be configured to be sent time tagged to the baseband equipment.

5.1.2 Orbit Measurement Service

The Ground Station receives orbit information and feeds the antenna control unit (ACU) with prediction files. As long as the antenna uses the prediction information to point to a spacecraft, no orbit measurement date can be collected. When the tracking system of an antenna is switched to Autotrack mode, orbit measurement data can be recorded.

Three different measurements are available:

• Angle data measurement
• Ranging data measurement
• Doppler data measurement

The measurements are stored in files and are available for customers.

Fig. 5-3 The 15m II S/X-band antenna in Weilheim

5.2 RF Compatibility Test Ground Station Weilheim

The objective of the RF compatibility test is to demonstrate the design compatibility between the satellite and the ground stations at the RF levels of the telemetry, telecommand and ranging signals. The compatibility tests are performed between representative models of the satellite (i.e. EM RF-SYSTEM (Engineering model) or also flight model for small satellites) and the Weilheim S-Band Ground Station (see Figure 5-4 below).

In the RF Compatibility test room (RF shielded measurement chamber), the EM RF-SYSTEM (the Spacecraft under test) interfaces with the station equipment via coaxial cables (hard wired) to reduce RF interferences from outside (s. Figure 5-5, compatibility test room configuration).

All measurement devices have to be calibrated before the tests are conducted.

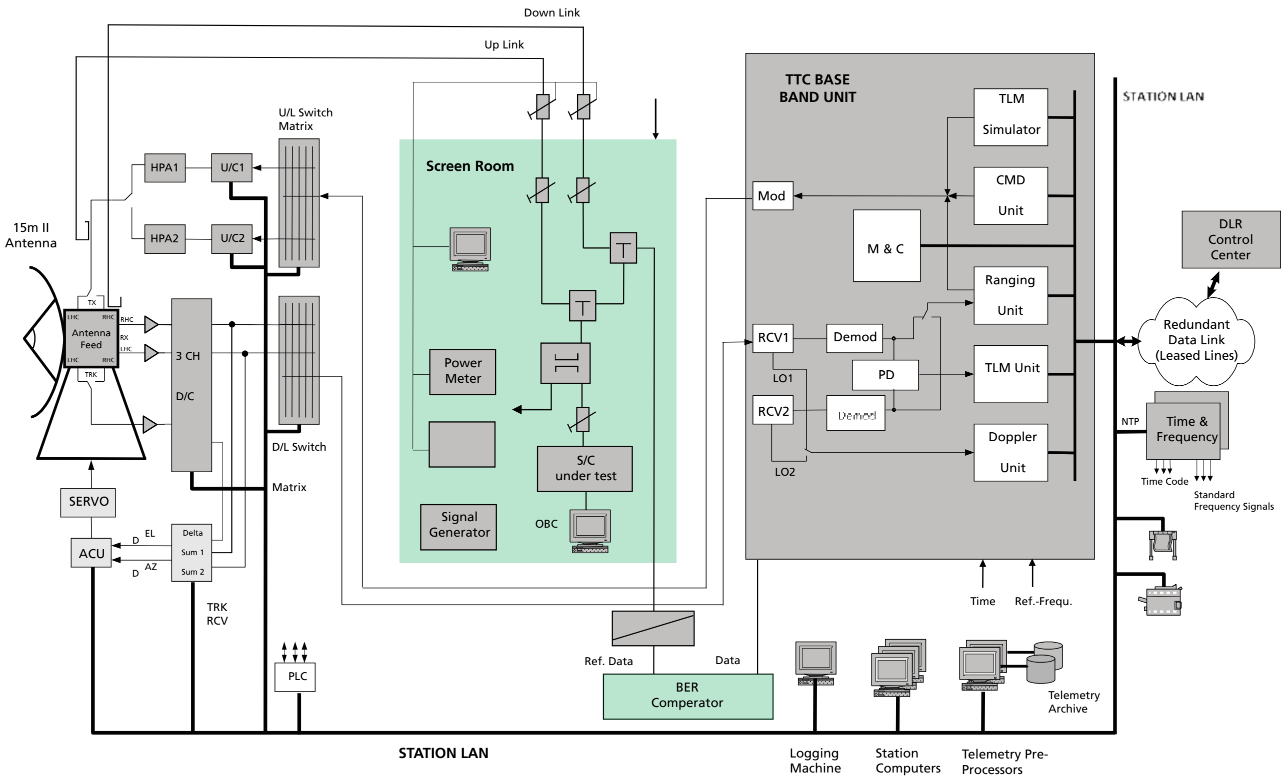
A compatibility test has five main topics:

• Spacecraft (S/C) Radio Frequency Tests
• Telemetry Tests
• Telecommand Tests
• Ranging Tests
• Earth Station Antenna Tracking System Tests

The S/C Radio Frequency Tests include the following: 1) S/C output power and its stability 2) S/C output frequency and its stability 3) S/C receiver signal threshold (minimum required uplink power for S/C receiver lock) 4) S/C receiver tracking bandwidth.

Telemetry (TM) tests include: 1) TM carrier suppression 2) Ground receiver TM threshold 3) TM Bit Error test (BER vs. Eb/No) 4) Uplink signal effect on TM 5) TM signal spectrum plots.

Fig. 5-4 RF Compatibility Test Configuration Weilheim G/S S-Band System with TerraSAR-X as DUT



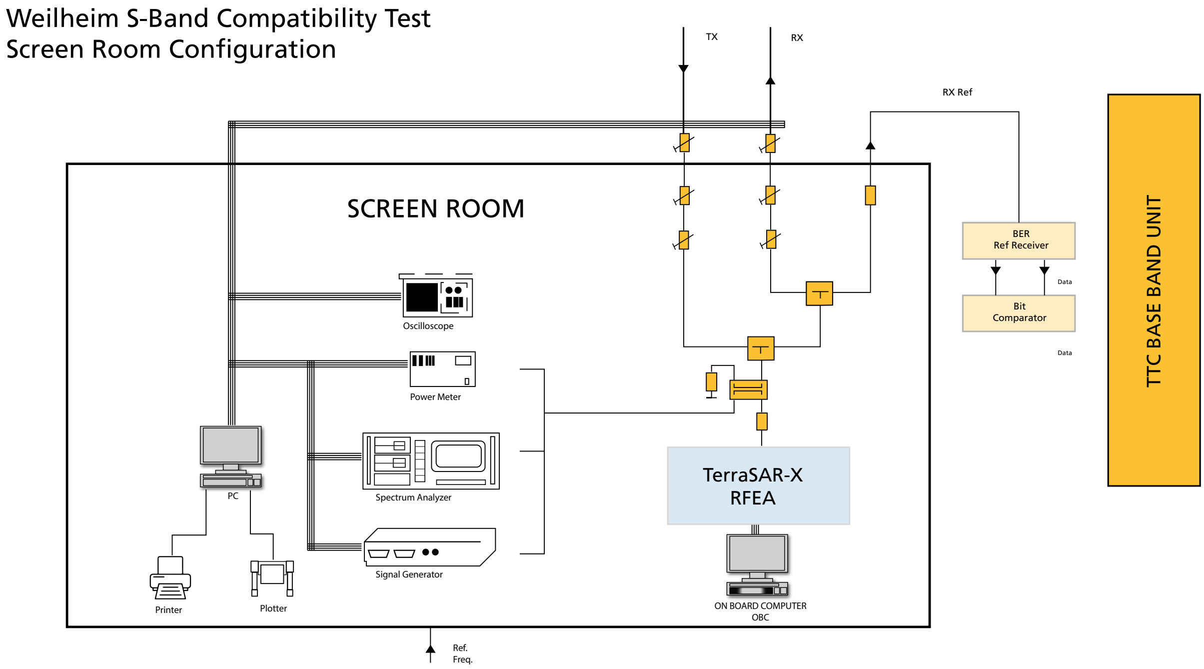


Fig. 5-5 RF Compatibility test room configuration with TerraSar-X as DUT

Telecommand (TC) tests include: 1) S/C receiver TC threshold (minimum required uplink power for TC reception) 2) Uplink modulation index variation.

Ranging tests include: 1) Ground equipment ranging delay 2) RF-Suitcase ranging delay 3) Overall ranging delay and signal threshold 4) Ranging downlink spectrum 5) Ranging downlink modulation index.

The antenna tracking system test determines the minimum required downlink signal level for tracking receiver signal acquisition.

There are essentially three phases of an RF-Compatibility test:

- Test preparation (test planning, resource planning, provision of equipment and measuring equipment; this is documented in the test plan and procedure)
- Test execution (documentation of the test results in a test report and documentation of deviations via NCR)
- Test follow-up (creation of the test report and mission-specific parameter lists)

The RF-Compatibility test plan and procedure was developed based on previous CCSDS Green-book, CCSDS 412.0-G-1, may 1992, now a silver book; CCSDS historical document available at CCSDS website.