Global supplier of telecommunications subsystems and equipment for satellites.
Tesat-Spacecom and the world of telecommunications

The roots of Tesat-Spacecom GmbH & Co. KG are embedded in today’s 100 years of industrial history of Telefunken. For four decades Tesat-Spacecom, based in Backnang, Germany, has designed and manufactured payload equipment for communication satellites. As a global equipment supplier for the satellite industry Tesat-Spacecom has 800 employees and achieved total sales of 158 million EUR in 2007.

The company has participated in almost 500 space projects. Tesat-Spacecom’s core product is the microwave power module. Moreover, Tesat-Spacecom has qualified laser crosslinks which operate at very high bit rates to transmit information between satellites. All ESA space qualified manufacturing processes including plating and soldering facilities are available at Tesat-Spacecom for the production of the flight hardware.

All tests are performed in the test area fully equipped with thermal vacuum and vibration test facilities, high and low power computer-controlled test benches.

History & Heritage

1949 AEG Fernmeldetechnik AG
1955 Telefunken GmbH
1967 AEG Telefunken AG
1983 ANT Nachrichtentechnik GmbH
1995 Bosch Telecom GmbH
2000 Bosch SatCom GmbH
2001 Tesat-Spacecom GmbH & Co.KG

Block Diagram of a Communications Payload
Satellite Communications Systems

Tesat-Spacecom’s space activities comprise system design, development, production, integration and testing as well as the management of satellite projects and communications equipment for space vehicles.

Payloads for communications satellites

Complete telecommunications equipment for the frequency ranges of 1.7/2.6 (L/S-Band), 4/6 GHz (C-Band), 8 GHz (X-Band), 11/12/14 GHz (Ku-Band), 20/30 GHz (Ka-Band) and 39/44 GHz (EHF-Band).

Payloads for broadcasting satellites

Complete telecommunications equipment for the frequency ranges of 4/6 GHz, 12/18 GHz and 20/30 GHz.

Earth exploration systems

Communications equipment for weather satellites and other earth observation and scientific satellites for the transmission of measured data to earth stations.

Space stations and space transport systems

Communications systems for information transfer between space stations and information exchange between platforms, scientific satellites, data relay satellites and with earth stations.
Projects and References

Tesat-Spacecom has supplied payloads or subsystems for the following space programs:

**ECS Eutelsat**
Complete telecommunications payloads for five satellites.

**DFS Kopernikus**
System leadership, development and supply of telecommunications payloads for three satellites and the drives for the solar generators and ground stations.

**TV-Sat**
Telecommunications payloads for two DBS satellites (250 W/ch).
Telecommunications equipment for TDF, Tele-X, Olympus.

**Artemis**
Development and manufacturing of the Ka-Band return repeater.
Euroskyway
Development and breadboarding of the data transmission subsystem for advanced multimedia satellites.

Satcom BW2
SHF Repeater for German MoD communication satellite.

The following weather/earth exploration satellites have received their payloads or subsystem from Tesat-Spacecom:

Meteosat
Telecommunications payloads for five satellites.

Envisat
Telecommunications subsystem in Ka-Band and X-Band for systems used for earth observation and scientific experiments.

Metop
3 complete data transmission subsystems for high data rates as well as the transmit unit for low data rates including antenna.

COMS
Payload for Korean weather satellite.

Helios II
Data transmission system including antenna.

Rocsat 2
Data transmission system for one satellite.

Radasat 2
Data transmission system for one satellite.

Cryosat
Data transmission system for two satellites.

SAR-Lupe
Data transmission system and pulsed amplifier subsystems for five satellites.

TerraSAR-X, Tandem-X
Data transmission system for the satellites (300 Mbps per channel).

Cosmo-Skymed
Data transmission system for four satellites.

Aeolus
Data transmission system.

THEOS
Data transmission system.

KOMPSAT 5
Data transmission system.

Customers

Europe:
- Thales Alenia Space
- Astrium
- ESA
- DLR
- OHB
- MoDs
- MIER
- IAI/Elta

USA/Canada:
- Space Systems Loral
- NGST
- Lockheed Martin Space
- MDA
- Boeing Space Systems
- JPL/NASA
- Orbital

Asia/Russia:
- CAST
- ISRO
- NTS, Sumitomo
- MELCO
- ETRI
- GASCOM
- RNIIKP

Since 1971, Tesat-Spacecom has delivered communication payload equipment for the above satellite projects.
Key components for communications satellites are the power amplifiers in the telecommunications payload. Four decades of experience enable Tesat-Spacecom to provide Travelling Wave Tube Amplifiers (TWTAs) for space applications. Today, Tesat-Spacecom has a 50 percent share of the world market for power amplifiers. In numerous communications satellites Tesat-Spacecom TWTAs have now accumulated almost 100 million operating hours in space. TWTA lifetimes of up to 18 years are usual.

Travelling Wave Tube Amplifiers

The TWTA is a key element for a satellite transponder. Tesat-Spacecom has provided TWTAs which satisfied requirements of NASA, ESA, Intelsat, Inmarsat, European, Asian and US commercial and military programs. Starting from frequencies at 1.5 GHz up to 60 GHz, Tesat-Spacecom has TWTAs on hand with RF output power ranges from 10 W up to 450 W.

High efficiency is required in order to optimize RF output power and heat dissipation. The RF performance characteristics such as high gain, gain flatness, low phase distortion and high linearity shall be combined with straightforward mechanical design which results in low mass and small dimensions.
The TWTA consists of the Travelling Wave Tube (TWT) mainly determining the RF performance and the Electronic Power Conditioner (EPC), designed and manufactured by Tesat-Spacecom, for power matching of the DC and bus interfaces.

The Tesat-Spacecom EPC is designed to be integrated with any TWT of the different TWT manufacturers by optimizing the high voltages for the individual approaches. The integration of the TWT and EPC as well as the testing of the TWTA are performed by Tesat-Spacecom.

Based on the technology of the current TWTA programs, Tesat-Spacecom has developed a new line of EPCs. The family now covers the RF output power range from 10 W up to 150 W. The EPCs are comprehensively qualification tested for quite a number of applications.
Dual Travelling Wave Tube Amplifiers

Dual TWTAS

The dual EPC is capable to operate two TWTs up to 150 W simultaneously. The two TWTs can be operated as single TWTAs independently or RF combined in order to provide 300 W of RF output power from radiation cooled or conduction cooled TWTs.
Microwave Power Modules (MPM)

The Microwave Power Module (MPM) is a compact amplifier consisting of our advanced technology Electronic Power Conditioner with integrated Tesat-Spacecom Channel Amplifier (CAMP) and Tesat-Spacecom Linearizer (LIN) in one housing. It provides many advantages as savings in mass, mounting area and simplification in payload integration, as well as better EMC characteristics and only one unique connection to the EPC for DC and all TC/TM functions of the MPM. Also available as Dual MPM with radiation cooled or conduction cooled TWTA.

New Developments:
Flexible Output Power Microwave Power Modules in Ka- and Ku-Band

Flex MPM
- In-Orbit adjustable RF output power via telecommand (3 to 4 dB) with milli second timely resolution
- Automatic compensation of phase and amplitude variation
- One TM/TC for EPC and CAMP

FDOC MPM
- In-Orbit adjustable and tunable LCAMP and TWTA
- Tuning and TWT parameters for control and power uploadable for ground and space via TM/TC
- Optional optical interface for telecommand and telemetry.
Solid-State Power Amplifier (SSPA)  
Linearizer (LIN)  
Channel Amplifier (CAMP)

Solid-State Power Amplifiers (SSPA)
Tesat-Spacecom supplies a wide range of solid-state power amplifiers in L-, S-, C- and X-Band for output power from 6 to 30 W. These equipment are designed for applications where size and mass are relevant.

The SSPA functions are as follows:
- Telecommands
  - SSPA ON/OFF
- Telemetries
  - SSPA ON/OFF Status
  - Main Bus Current
  - RF Output Power
  - Temperature

Linearizers (LIN)
The Linearizer has a wide band performance in C-, Ku-, Ka-Band. It is suitable for different space applications e.g. as stand-alone equipment or for use in the MPM-concept (LTWTA). The device is fully temperature-compensated.

Channel Amplifiers
The Channel Amplifier (CAMP), which is one of the key components of the repeater, amplifies the input signal to an output signal matching the input power level of the TWT. It is also available as Linearized Channel Amplifier (LCAMP), which achieves an amplitude expansion for the input signal to compensate for the amplitude compression of the TWT in order to linearize the TWT.
Low-Noise Amplifiers

The LNA has a wide band performance in the Ka-Band uplink frequency range from 27 to 31 GHz. The LNA hybrid which is only 41 x 20 x 9 mm in size and with a mass of 32 gr is fully equipped with custom MMIC circuits. It is suitable for different space applications as stand-alone equipment like LNA, receivers/converters or directly mounted onto fixed beam antennas. The typical noise figure is 2.5 dB and the gain can be adjusted in the range from 25 to 40 dB. The picture shows the LNA hybrid in a typical stand-alone LNA configuration which is capable to be operated from a simple DC supply and a satellite’s TM/TC system. Special features like gain setting or high precision gain compensation circuits can be implemented on customers’ requirements.

Tunable Down Converters

Typical application for the Tunable Down Converter (TDC) are Ka- and Ku-Band regenerative payloads with on-board processing capabilities where flexible channel assignment is required. The equipment down-converts eight input channels in the 5.5 GHz region to one dedicated output channel at 500 MHz with an internal PLL synthesized oscillator. The device uses MMIC and hybrid technology to achieve highest packaging density and lowest power consumption. The TDC comprises four independent converter chains, 4 independent synthesizers and a dual redundant DC/DC converter as well as all necessary TM/TC circuits.

Upconverters

7/20 GHz

Typical application for the 7 to 20 GHz upconverter are commercial and governmental satellite transmit sections. The equipment is electrically and mechanically subdivided into the mixer and the channel amplifier (CAMP) part. The mixer is designed for broadband LO and IF frequency performance to cover the requirements in fast frequency hopping applications. The CAMP covers the whole Ka-Band downlink frequency range from 17 to 21 GHz and is connected to the mixer via a semi-rigid cable. DC Supply for the upconverter is ± 6.5 Volt. The single modules can be assembled on a common mounting plate or directly to the EPC where DC and TM/TC interfaces can simply be realized. Other frequencies are available.
Tesat-Spacecom has an extensive experience in the field of satellite filters. A multitude of input and output multiplexers and filters from L- to Ka-Band have been designed, manufactured and qualified and flown successfully in various programs in the last four decades. Tesat-Spacecom individually designs to customer requirements using advanced CAD tools and dedicated manufacturing facilities.

Filters and Multiplexers

Tesat-Spacecom has advanced inhouse software for the design of all kinds of filters such as Tchebyscheff, elliptic function, pseudoelliptic function, and linear phase (self equalized) asymetrical characteristic, and for the effective simulation and optimization of multiplexers. All necessary space qualified manufacturing processes including silver plating and soldering facilities are available at Tesat-Spacecom for the production of the flight hardware. All tests are performed in the test area fully equipped with thermal vacuum and vibration test facilities, high and low power computer-controlled test benches.

Input Multiplexers and Multiplexer Assemblies

The function of an input multiplexer (IMUX) is to separate the individual channels out of the incoming broadband signal. Highly demanding electrical performance requirements have to be met by the input multiplexers. They are also available as Input Multiplexer Assemblies including switches, low-pass filters, hybrids, circulators, isolators etc.

The main features of the Tesat-Spacecom Input Multiplexers are:

- Applications in X-, Ku-, Ka-Bands
- Large number of channels per multiplexer
- Space-qualified and flight proven designs
- Superior performance
- Excellent temperature stability
- Quasi-elliptic filter functions
- Self-equalized or external equalization
- Very low losses due to high practical Q factor
- Large variety of useful channel bandwidth
- Prediction and control of higher modes
- Superior compact design

Output Multiplexer and Multiplexer Assemblies

Their function is to combine the power signals coming from the power amplifiers and to feed the antenna network. Tesat-Spacecom has excellent facilities to design and manufacture microwave output multiplexers. These multiplexers are always critical components as far as loss, mass and volume are concerned.
Main features of the Tesat-Spacecom Output Multiplexers are as follows:

- Designs available for L-, X-, Ku- and Ka-Bands
- Variety of filter grade and functions available
- Contiguous, noncontiguous, and quasi-contiguous filter characteristics
- Inhouse developed RF simulation and optimisation software tools provide exact full wave modelling including influence of tuning screws and accurate prediction of higher order modes
- No breadboarding required
- Simulation capability up to 32 channels
- Realisation of 14 channel multiplexers in C-Band and 18 channels in Ku-Band
- Full band multiplexing: 2 GHz in Ku-Band and 800 MHz in C-Band
- Multiplexing with non-monotonic channel sequence to simplify waveguide routing
- Thinwall INVAR waveguide filter technology
- As an alternative temperature compensated aluminium waveguide filters
- Fully integrated subsystems available (incl. isolators and switches) for optimum RF performance

- Full RF, mechanical, and thermal custom design and layout capability
- Combline, herring bone and mixed configurations

- Heritage with assemblies with aluminium and honeycomb base plate
Receive/Transmit Diplexers

Tesat-Spacecom has established a unique high performance diplexer approach for separation of the receive and transmit bands. The design is based on a completely integrated unit – comprising a high pass and a corrugated low pass filter that are directly interconnected with a sophisticated broadband waveguide branching for

- no tuning
- low insertion loss (<0.15 dB)
- good matching properties (<26 dB)
- high receive/transmit band isolation
- high power handling capability.

Passive Components for Space Applications

These products include ferrite devices, couplers, power combiners and splitters, transitions and low/high power terminations for L-, S-, C-, X-, Ku- and Ka-Bands.

Waveguide Switches

Tesat-Spacecom also manufactures and supplies waveguide switches operating in the range from 4 to 40 GHz for redundancy switch matrices in satellite payloads.

The main features of the Tesat-Spacecom switches are:

- Optimum RF performance
- Covering C-, X-, Ku-, Ka-Band
- C-type and R-type switches
- Single switches, switch blocks and switch matrices
- Sequential access actuators with high torque margin
- Magnetically latching
- Mechanically simple design with minimum number of piece parts
- Highest reliability (life test up to 280,000 actuations under extreme conditions)
- RF power handling capability (up to 1400 W in Ku-Band)
- High vibration and shock load capability (up to 70 g rms)
- Reed switch telemetry
- TM/TC interface with 9-pin connector
RF Subsystem Modules

For four decades, Tesat has performed on more than 30 programs from system level to subsystem, which reflects the high integration level of the Tesat products. The company offers core products and various equipment in microwave integrated circuit technology.

Tesat’s product scope includes:

- Tx-Section for Ku- and Ka-Band
- X-and Ka-Band subsystems with > 600 Mbit/s in one channel (equipment capability)
- Small Repeaters (L-, S-, C-, X-, Ku-, Ka-Bands)
- RF Intersatellite Link terminals
- Digital payloads for small satellites
- Radar HPA Subsystems
- Modulators and Demodulators

**Modulators**

Since 1980, Tesat has been working on modulators for regenerative transponders and data transmission systems.

High Speed X-, Ku- and Ka-Band Direct Modulators:
- BPSK/QPSK/S-QPSK/8PSK Modulation
- Data Rates up to 700 Mbps (equipment capability)

DVB-S Direct Ka-Band Modulators:
- QPSK Modulation
- Digital Pulse Forming
- Data Rate 56 Mbit/s
- Includes data formatter ASIC

Highly Integrated Modulator Assemblies:
- Includes up to 10 DVB-S Modulators
- Includes LOs, Power Supply, Redundancy Switches
- Flexible and Modular Design

**Demodulators**

Tesat-Spacecom has been working on Digital Demodulators and Signal Processing Systems since 1980:

- QPSK Demodulator (Ku-band)
- Development of IDR Ground Stations
- Fundamental work on digital Demux (various patents)

In-House ASIC Design Capability:
- Proven ASIC design flow
- Frequency Demultiplexers, Demodulators, Decoders

128 Channel Multi-Carrier Demodulator:
- MF-TDMA waveform
- 128 channels à 500 kbps
- Fully digital implementation using rad-hard ASIC
- EM under ESA OBP program 1997-1999
The series of successful optical communications with Tesat LCTs between the U.S. NFIRE and the German TerraSAR-X satellites set a milestone in 2008. The data rate of 5,500 Mbps is a new landmark for intersatellite communication.

Both satellites operate in low Earth orbits and come closer than 5,000 km several times a day. At those occasions laser links can be established for up to 20 minutes duration. When closing such a link, the main job is to aim the communication laser beam precisely onto the distant target satellite and keep it there while it passes by at a speed of about 25,000 km/h. This corresponds to a person on ground aiming at an individual window of an aircraft operating at high altitude.

With this successful demonstration Germany has taken the lead in a strategic field of technology: Laser Terminals will be important elements of the future high performance data relay satellite infrastructure that supports real-time data links from ground to Earth observation satellites, scientific missions or high flying aircraft with global, ubiquitous coverage.

The development of those terminals has been sponsored by the Ministry of Economy and Technology (Bundesministerium für Wirtschaft und Technologie (BMWi)) via the German Space Agency (DLR Raumfahrtagentur); the Ministry of Defence (Bundesministerium der Verteidigung (BMVg)) has advocated and managed the cooperation with the U.S. DoD for the in-orbit demonstration of the system.

Pioneering Telefunken engineers in Backnang built optical communications with the first free space and fibre optical transceivers during the 1960s. From these roots Tesat-Spacecom engineers have been working continuously on applying this to optical satellite communications.

Unique Competitive Edges for our Customers convinced Motorola in 1998 to contract Tesat for the Celestri and Teledesic programs to build 500 terminals for a LEO constellation. In the Teledesic program, Tesat performed an extensive risk reduction program for all new laser comms technologies, including extensive radiation and in-orbit vibration validation.

Today Tesat Laser Terminals have not only communication performance characteristics far superior to those of earlier developments of the European Space Agency ESA, they are also much smaller and more efficient.

**Laser Crosslink Technology**

Link robustness and immunity against sunlight are decisive factors for security applications, disaster relief or commercial connectivity providers. Homodyne BPSK (binary phase shift keying) is superior to all other optical modulation schemes and offers highest sensitivity for both communication and tracking. It is also the only modulation scheme providing full immunity against sunlight since electrical filtering by homodyne detection is more selective than optical coatings used in direct detection filtering. These Tesat advantages apply fully to LEO and GEO intersatellite links.
For system level testing a most advanced testbed was set up for the verification of all laser crosslink performance features under simulated operational in-orbit parameters.

Laser diode reliability and availability is today a key parameter. Starting with SILEX, Tesat has continuously run qualification tests on statistically significant samples of all relevant laser diode manufacturers. Large and prominent laser diode suppliers have pulled out of the market since the dot-com times. Yet over the years Tesat accomplished to form an exclusive supplier network and a unique know-how base of quality screening & mounting. Sustained availability and technology improvement is secured by embedding the Tesat supply in a German government backbone of institutions for car industry.

A unique ultra-compact receiver combines all optical elements for receive and transmit beam separation as well as local oscillator superposition. This miniature size element (about 10 cm height) replaces a complete optical bench of standard designs. Small size allows excellent alignment precision and rock-solid long-term stability over the mission life.

Receiver and RF Electronics Heritage

The Tesat optical terminal builds upon the SILEX receivers heritage and a full toolbox in the RF telecommunications field: Amplifiers, Linearizers, electrical power conditioners, controllers and TM/TC interfaces.

RF modulator driver

Outlook

Tesat will deliver in 2008 the next generation first flight model to the TanDEM-X satellite under contract of the German Space Agency. This long range model is capable to provide links to and from geostationary (GEO) relay satellites and unprecedented data rates of 2'800 Mbps.

These next generation terminals are planned to be installed as GEO relay stations for example on Alphasat and the European Data Relais Satellite.

GEO relay anchor satellites with optical terminals will provide nearly uninterrupted data links to low Earth orbiting satellites or other scientific missions (Moon, Mars) that require real-time data links with the user on-ground. The need of multiple ground stations around the globe and frequency license obstructions are then obsolete. This capability is a precondition for numerous commercial and scientific missions but also for many security-sensitive applications (environmental monitoring, disaster relief, border security, defense).
Serving Science – The optical equivalent of an RF reference oscillator

For non-communication applications Tesat offers stand-alone lasers. The dimensional stability of a temperature stabilized laser crystal is transferred onto the laser frequency which can serve as a metrology tool. Tesat customises the laser to specific flight mission requirements upon request:

- **RLU standard package (pic 1):** 25 mW output CW @ 1064 nm
- **RLH advanced frequency stability package (pic 2):** It combines exact tunability (two phase locked lasers with up to 5 GHz offset) and long term frequency stability by anchoring the master laser to a passive high-finesse ULE reference cavity (pic 3)
- **Pulsed Q-switch laser (pic 4):** Repetition rate 5 to 10 KHz with about 40 μJ/pulse
- Optimized for beam quality and μ-radian pointing
- Optional: Phase/amplitude modulation including modulator driver
- Optional: Output power amplification by space qualified fiber amplifier (polarization maintaining, single mode) to about 1.5 W
- Tesat laboratory capability is 10 W in both bulk and large core fiber
- Optional: Further improved long-term frequency stabilization using iodine cell stabilization loops
- Optional: 1319 nm wavelength
Based on its extensive experience with a variety of components, Tesat-Spacecom is well qualified to tackle any space parts engineering and procurement job.
Our Representative in the USA and Canada:

Peter Lüst
Electronic Note Space Systems
300 Esplanade Drive,
9th floor, Suite 900,
Oxnard, California 93036, USA

Telephone 805 – 981 – 91 78
Telefax 805 – 981 – 91 47
peter@electronicnote.com

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