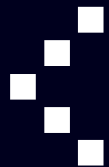




# Facts, Products and Services

Full-line supplier of telecommunications subsystems and equipment  
for satellites and spacecraft.



# Tesat Spacecom and the world of telecommunications

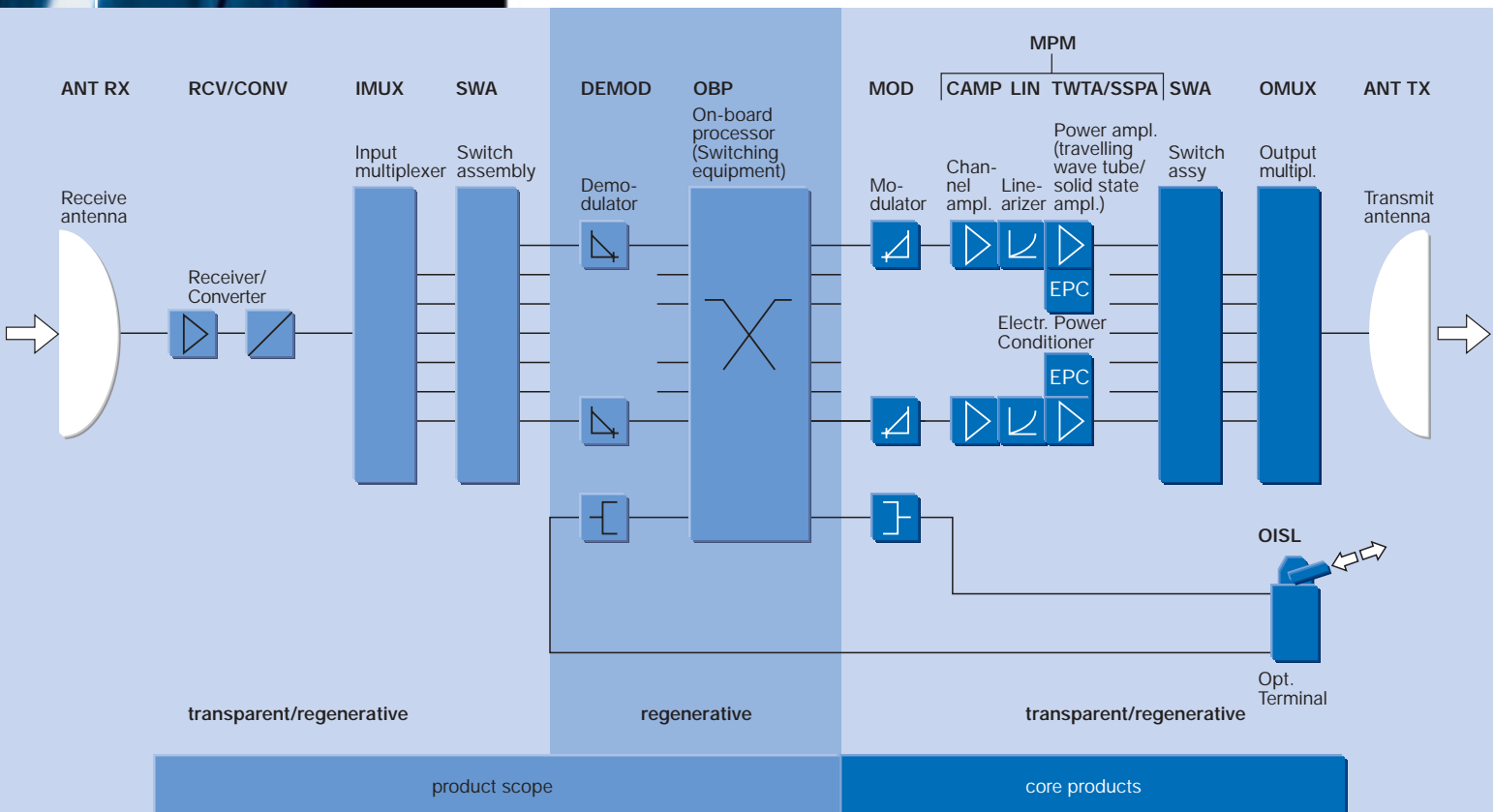
Tesat-Spacecom GmbH & Co. KG, based in Backnang, Germany, designs and manufactures payload equipment for communications satellites. It has 700 employees and achieved total sales of 103 million EUR in 2001.

The company has participated in more than 350 space projects. Tesat-Spacecom's core product is the travelling-wave tube amplifier which is supplied to more than 45% of the open world market. Moreover, Tesat-Spacecom is developing laser crosslinks which operate at very high bit rates to transmit information between multimedia system satellites.

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.

Block Diagram of a Communications Payload





*Thermo vacuum chambers for testing space equipment*



*In the scope of the Artemis project, Tesat-Spacecom was responsible for development and manufacturing of the Ka-Band return repeater*

## 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 12/18 GHz.

### **Earth exploration systems**

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



*Output multiplexer in thermo vacuum chamber*

### **Space stations and space transport systems**

Communications systems for information transfer within 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.



- Express AM '02
- MT Sat '03
- Stellat '02
- Metop '01
- Helios '01
- Eurasiasat '00
- IRS '00
- GE12 '02
- NSS 6 '02
- Olympus '89
- Eutelsat III (6) '90
- Insat1-D '90
- Telstar 8 '02
- TDRS F7 '02
- Turksat '96
- Insat '95
- Asiasat '95
- Spat '00
- ERA '01
- Echostar 8 '01
- Insat II (2) '92
- Poseidon '00
- Hispasat 10 '02
- Telecom 2 (4) '92
- Intelsat VII (5) '93
- NSat '00
- Brazilsat '02
- IRS '94
- Hispasat (3) '92
- GE 7/8/9 '00
- I-Sky '02
- Koreasat (2) '94
- Meteosat (5) '89
- Insat 3 '00
- Echostar7 '01
- Inmarsat 3 (5) '95
- Tele-X '89
- Artemis '00
- Contour '02
- Echostar 1/2 '93
- DFH 2 (3) '89
- MSG '00
- Intelsat 10 '03
- CCS '95
- DFE-Kopernikus (3) '89
- Express '99
- Hot Bird 7 '03
- EOS '96
- FEF (2) '86
- Koreasat '99
- IP-Star '03
- Arabsat 2 (2) '86
- TDRS F1-F6 (6) '83
- Intelsat KTV '99
- L-Star '88
- LWI '00
- Tempo (2) '96
- Anik B '78
- ST 1 '98
- NSAT 110 '00
- Mars Surveyor '96
- ATV
- Planner 1/2 '98
- Envisat '98
- MTP '98
- Echostar '98
- New Bird '01
- Hot Bird (5) '96/98
- Intelsat IV A (2) '75
- Astrolink
- Telecom 2 F4 '97
- New Bird
- DFH
- Euroskyway
- Safelcom
- XM Radio '02
- NSS7 '02
- Mabuhay '97
- Pansatsat (4) '97
- Telstar '97
- Astar '97
- Eutelsat
- Optus C '02
- Rainbow '03
- AMS-19/18 '03
- Redansat '03
- Rosatl '03



### DFS Kopernikus

System leadership, development and supply of telecommunications payloads for three satellites and the drives for the solar generators.

### TV-Sat

Telecommunications payloads for two satellites.

Telecommunications equipment for TDF, Tele-X, Olympus.

### Artemis

Development and manufacturing of the Ka-Band return repeater.

### Euroskyway

Data transmission subsystem for advanced multimedia satellites.

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

### Meteosat

Telecommunications payloads for five satellites.

### Envisat

Telecommunications equipment for systems used for earth observation and scientific experiments.

### Metop

Complete data transmission subsystems for high data rates as well as the transmit unit for low data rates.

### Helios II

Data transmission system for two satellites.

### Rocsat 2

Data transmission system for one satellite.

*Since 1971, Tesat-Spacecom has been involved in the above satellite projects*

### Radarsat 2

Data transmission system for one satellite.

### Cryosat

Data transmission system for one satellite.

### Sar-Lupe

Data transmission system and pulsed amplifier subsystems for five satellites.

### Terra-Sar

Data transmission system and pulsed amplifier subsystem for one satellite.

### Cosmo

Data transmission system for one satellite.

### Customers

#### Europe:

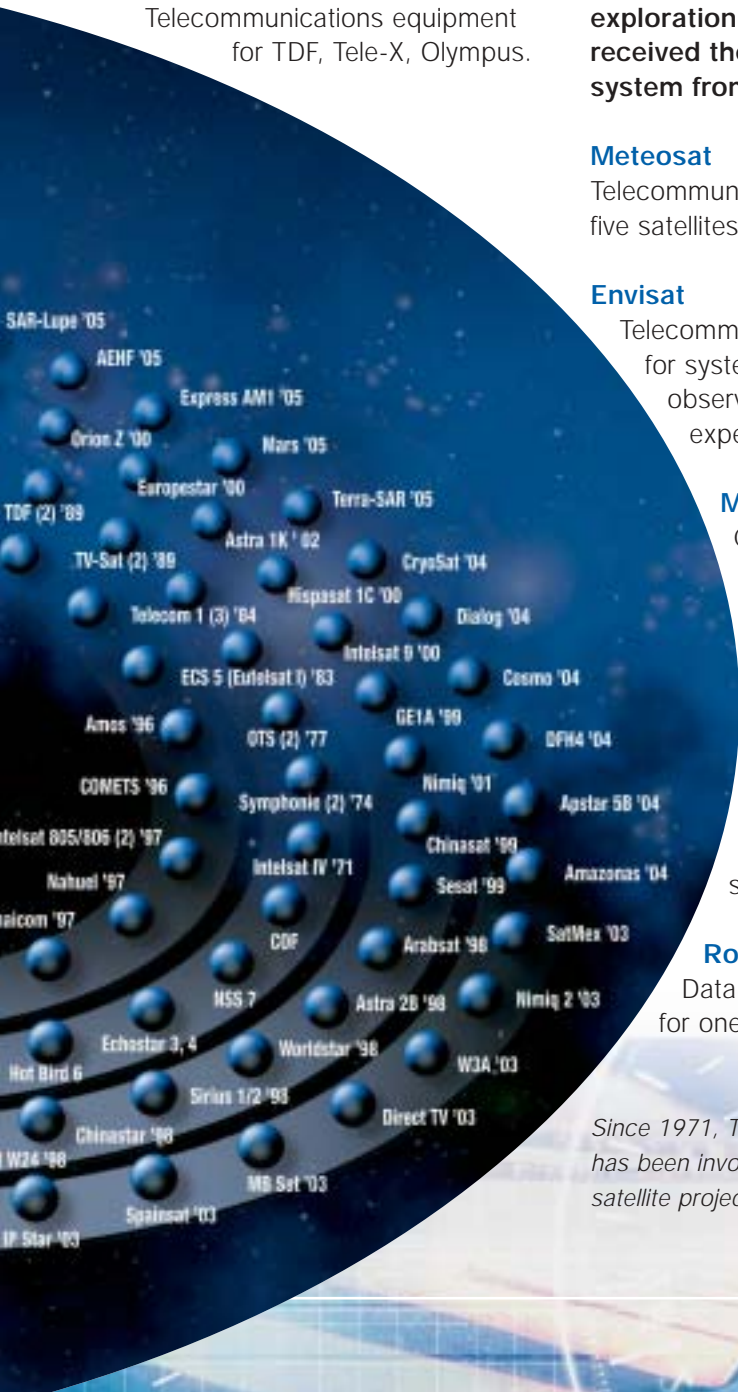
- Alcatel Space
- Astrium
- Alenia Aerospazio
- ESA
- DLR
- OHB

#### USA/Canada:

- Space Systems Loral
- TRW
- Lockheed Martin Space
- EMS
- Boeing Space Systems

#### Asia:

- CAST
- ISRO
- NEC
- MELCO



Key components for communications satellites are the power amplifiers in the telecommunications payload. More than 30 years of experience enable Tesat-Spacecom to provide Travelling Wave Tube Amplifiers (TWTAs) for space applications. Today, Tesat-Spacecom has a 45 percent share of the world market for power amplifiers. In numerous communications satellites Tesat-Spacecom TWTAs have now accumulated 10 million operating hours in space without failure. TWTA lifetimes of up to 15 years are usual.

## Travelling Wave Tube Amplifier

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 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

phase distortion and high linearity shall be combined with straight forward 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.

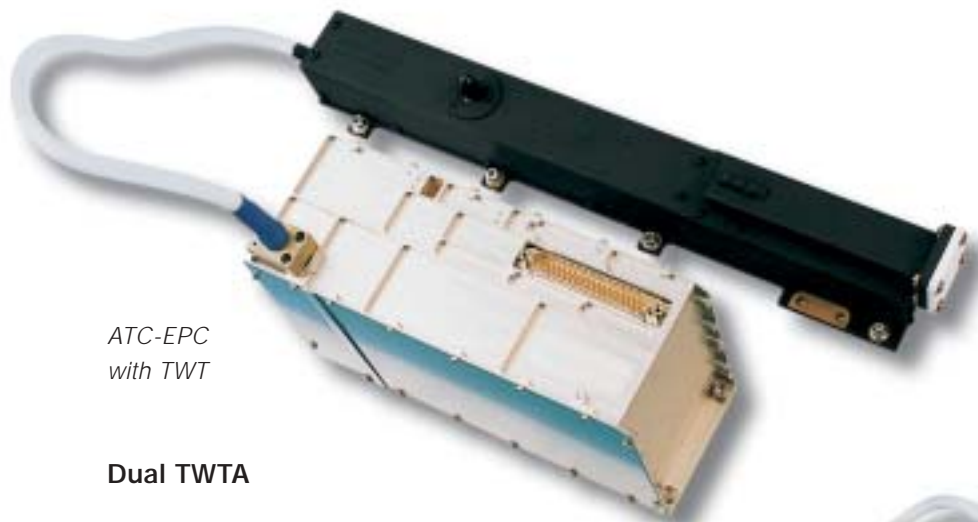
power and heat dissipation. The RF performance characteristics such as high gain, gain flatness, low

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.

*Eurasiasat  
Ku-Band TWTA*



*Tesat-Spacecom EPC family*



*ATC-EPC  
with TWT*



*ATC-L EPC*

**Dual TWTA**

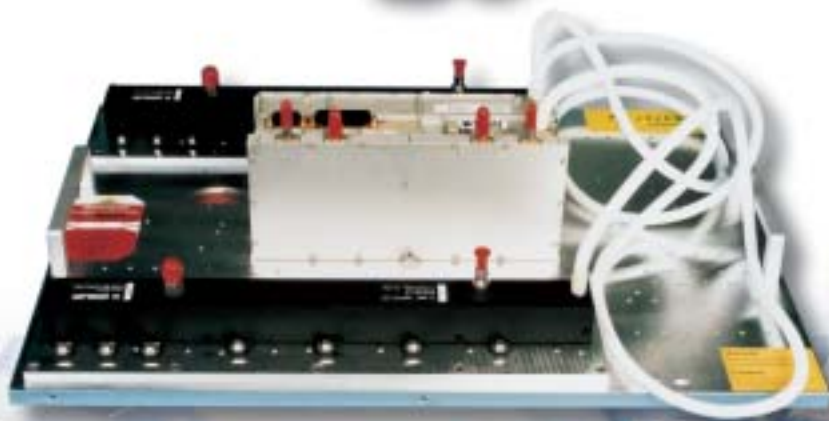
The dual EPC is capable to operate two TWTs up to 150 W simultaneously. The two TWTs can be operated as single TWTAs independently or RF combined in order to provide 290 W of RF output power from radiation cooled or conduction cooled TWTs.



*Dual TWTA*

**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). 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.



*Dual MPM*

- 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 in various programs
- in the last 30 years. Individual designs to customer requirements using advanced CAD tools and dedicated manufacturing facilities.

## Filters and Multiplexers

Tesat-Spacecom has excellent inhouse computer programs for the design of all kinds of filters such as Tchebyscheff, elliptic function, pseudoelliptic function, and linear phase (self equalized) asymmetrical characteristic, and for the effective simulation and optimization of multiplexers. All necessary space qualified manufacturing processes including EDM (Electrical Discharge Machining), 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 requirements of the electrical performance have to be met by the input multiplexers. 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 L, S, C, 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
- Selfequalized or external equalization
- Very low losses due to high practical Q factor
- Large variety of useful channel bandwidth
- Prediction and control of higher modes
- Compact design

### Output Multiplexer and Multiplexer Assemblies

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. Their function is to combine the power signals coming from the power amplifiers and to feed the antenna network.



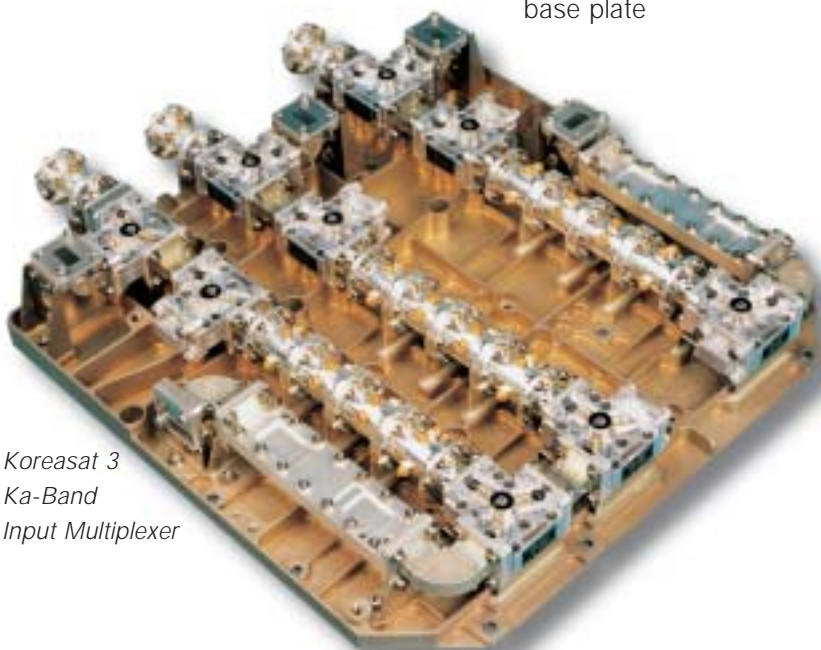


Main features of the Tesat-Spacecom Output Multiplexers are as follows:

- Designs available for L, S, C, 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
- Fully integrated subsystems available (incl. isolators and switches) for optimum RF performance
- Full RF, mechanical, and thermal custom design and layout capability

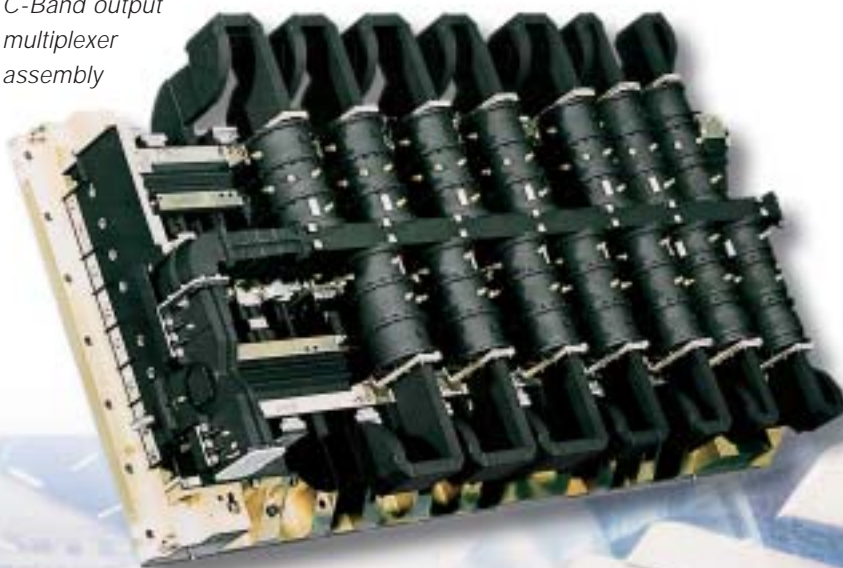
- Combine, herring bone and mixed configurations

- Heritage with assemblies with aluminium and honeycomb base plate



*Koreasat 3  
Ka-Band  
Input Multiplexer*

*Intelsat 805/806  
C-Band output  
multiplexer  
assembly*





## Filters and Passive Components

### Receive/Transmit Band Diplexers

Satellite antenna feed systems are generally exposed to extreme environmental conditions as for example temperatures ranging from  $-120\text{ }^{\circ}\text{C}$  to  $+140\text{ }^{\circ}\text{C}$ . Especially for such applications, Tesat-Spacecom has established a unique high performance diplexer approach for separation of the receive and transmit bands each served by one polarisation of a common antenna. 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.

This integrated approach allows the realisation of the diplexer by state-of-the-art CNC milling techniques from silverplated aluminium.

Tuning is avoided to cope with the inherent demands for feed system applications, namely

- low insertion loss ( $<0.15\text{ dB}$ ),
- good matching properties ( $<26\text{ dB}$ ),
- high receive/transmit band isolation,
- flat amplitude and group delay response and
- high power handling capability.

### Passive Components for Space Applications

Tesat-Spacecom's passive component product scope is rounded up by components for communication satellite payloads and higher level integrated sub-assemblies or stand-alone units.

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



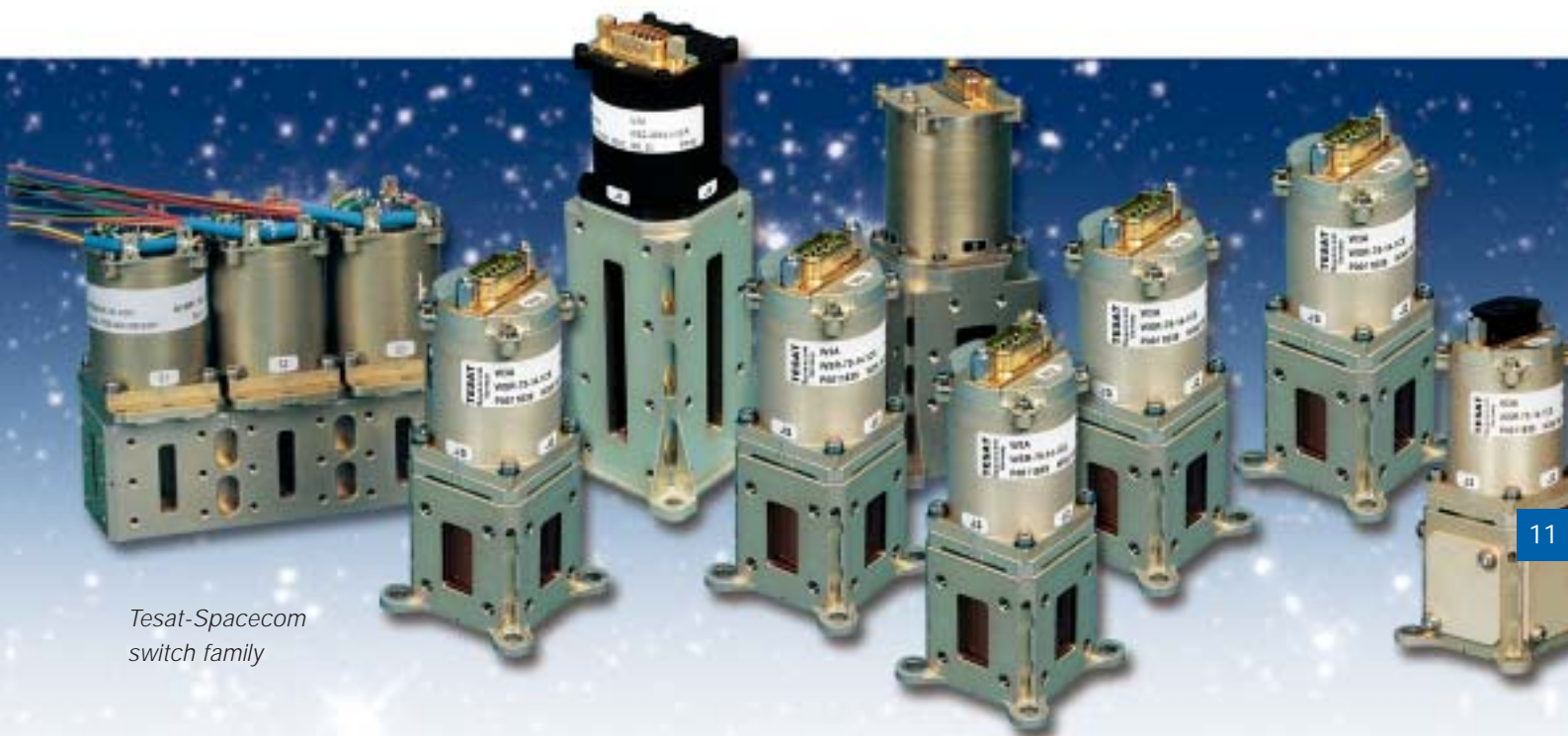
*Ka-Band Diplexer*



*Passive Components for Space Applications*



## Microwave Switches



*Tesat-Spacecom  
switch family*

Tesat-Spacecom also manufactures and supplies waveguides 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 in every position
- Mechanically simple design with minimum number of piece parts
- Highest switching reliability (life test up to 280,000 actuations under extreme conditions)
- RF power handling capability (up to 1400 W in Ku-Band)
- High level vibration and shock load capability (up to 70 g<sub>rms</sub>)
- Reed switch telemetry
- TM/TC interface with 9-pin connector

## Microwave Solid-state Equipment for Space Applications

Tesat-Spacecom supplies a wide spectrum of microwave solid-state equipment in frequency ranges from 1 GHz up to 30 GHz. Core products are linearizers, channel amplifiers, modulators and demodulators. The equipment is designed for applications where high reliability is required, corresponding to an orbital lifetime from 7 up to 15 years, which is proven in several satellite programs e. g. ECS, TV-Sat, DFS, Intelsat and Inmarsat.

The concept of modular design used in these equipment allows a high degree of flexibility and custom design capability for particular technical requirements. The microwave modules are realized in MIC and MMIC technologies, whereas the regulators and control circuits are assembled on PCBs. The MIC and PCB circuits are manufactured by Tesat-Spacecom in accordance with ESA and NASA standards.

*X-Band Modulator*



*PPF Ka-Band Modulator*



## Optical Terminals for Inter-Satellite Links



*LEO satellite system with optical inter-satellite links*

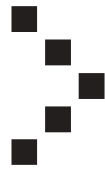
Tesat-Spacecom Coherent Laser Communication Terminals for Inter-satellite Links (ISL) are the result of more than a decade of development expertise in the field of free space optical communications and Tesat-Spacecom's broad knowledge of commercial space systems production. The terminal form is a coherent, high data rate communication system with homodyne receivers operating at 1064 nm. They provide

- user data rates of up to 10 Gbps duplex
- ample link margins

- interruption free communication even during sun pointing
- immunity to commercial space vehicle micro-vibrations
- high operational flexibility
- low mass and small dimensions
- simple integration on space vehicle
- good reliability for extended lifetime

The Tesat-Spacecom Coherent Laser Communication Terminal (CLT) product family for LEO-LEO and GEO-GEO commercial ISL applications derives its high-grade maturity from proven and extensive

European precursor activities in the field of optical communications. Direct advantage has been taken of the current Tesat-Spacecom optical terminal development programs of the German National Space Agency (DLR-LCT) and the European Space Agency ISL-TFE program for the development of an ISL optical receiver frontend. These activities led to the current world-class-best modular product family optimized for customized commercial applications. Space qualification and production start for LEO-LEO terminals is scheduled for the year 2002.



## Future Developments

### V-Band 60 GHz TWTA

Technical characteristics:

Frequency range:	59 to 64 GHz
RF output power:	< 25 W
Input voltage:	50/70/100 V
DC input power:	70 W
DC output power (EPC):	62 W
Efficiency (EPC):	91 %
Cathode voltage (max):	20 kV
Dimension (w/o TWT):	296 x 90 x 135 mm <sup>3</sup>
Mass:	EPC: < 2300 g, TWT: < 1200 g

### X-Band Modulator/Transmitter (XTRA)

Technical characteristics:

Frequency Range:	7.2 to 8.5 GHz
Modulation:	BPSK/QPSK/O-QPSK
Encoding	Differential (configurable)
Data Rate:	700 MBps max
Phase Imbalance:	< 4 Deg. pp
Amplitude Imbalance:	< 0.4 dB pp
Symbol Transition Time:	< 300 psec
Duty Cycle (Symbol)	48 % to 52 %
Output Power:	XMOD -10 to +0 dBm commandable XTRA 3 Watt
Carrier Frequency	7.2 GHz to 8.5 GHz
Commandable Synthesizer	
Bandwidth	500 MHz
Frequency Resolution	5 MHz
Frequency Stability:	±1 ppm vs. temp. ± 5 ppm over 5 years
Mass	XMOD 650 gramm, XTRA 950 gramm
Volume:	XMOD 165 x 7 x 40 mm (0,5 ltr.) XTRA 165 x 75 x 55 mm (0,7 ltr.)
Power Consumption:	XMOD 7 Watt, XTRA 23 Watt
Data Interface	I/Q Data + Clock or 8 Bit Parallel + Byte Clock
Main Bus Voltage	21 Volt to 35 Volt





## Parts Procurement Agency

*Active phased-array antennas*



*Based on its extensive experience with a variety of components, Tesat-Spacecom is well qualified to tackle any space parts engineering and procurement job*

15

A major factor in planning and implementing space projects successfully is to select and procure the optimum electronic components.

Tesat-Spacecom's in-house Hi-Rel parts procurement department carries out the selection, specification, most economic procurement, approval and supply of all Hi-Rel parts for Tesat-Spacecom space projects.

In addition to covering its own needs, Tesat-Spacecom offers this service to other companies as a procurement agent service.

Tesat-Spacecom has acted as central parts procurement agent for numerous space projects of which the most recent projects are the European Robotic Arm, Meteosat Second Generation and the Columbus Orbital Facility.

Our service bundles the products that are available on the world market in a parts procurement system that is geared to our

customers' requirements and can cope with tasks of all kinds and sizes.

Tesat-Spacecom has gained excellent knowledge of part types, their performance and technologies from extensive procurement activity on the world market. This is rounded off by our outstanding know-how and connections with the Hi-Rel component market.

Tesat-Spacecom's parts procurement department has been in operation without interruption since 1972: Procurement for more than 90 projects, including 10 complete projects, and more than 30 as a procurement agent, with over 14,000 different lots and 8 million piece parts being procured. Parts have been procured from 42 European, 77 US and 3 Japanese manufacturers.



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