Bosch Telecom GmbH has an extensive experience in the field of passive components for space applications. A multitude of filters, multiplexers and components from L- to Ka-band and frequencies of up to 30 GHz have been designed, manufactured and qualified in various programs in the last 30 years.
Bosch and the World of Telecommunications

Robert Bosch GmbH is a worldwide company with a turnover of almost DM 50.3 billion. In the Bosch Communications Business Sector, about 19,000 employees work in communications technology. Its share of total Group turnover in 1998 was 10%, i.e. DM 5.0 billion.

In the Space Communications sector, Bosch develops and manufactures communication equipment and systems for satellites and space vehicles. Bosch’s main space products are travelling wave tube amplifiers, multiplexors and switches as well as solid-state equipment. Moreover, Bosch is developing optical transmission systems which operate at very high bit rates to transmit information between multimedia system satellites.

In the Public Networks sector, Bosch is active in the transmission, network access and switching technology. The company delivers fiber-optic and radio-based transmission systems complying with the SDH standard, ISDN network terminals, as well as switching systems of the EWSD technology.

In the Private Communications Networks sector, Bosch develops, manufactures, and markets ISDN communications systems.

In the Terminals sector, Bosch has mobile telephones in its product line which comply with the GSM and DECT standards.

In the Security Systems sector, Bosch offers fire-alarm and burglar-alarm systems.

The Broadband Networks sector is one of the largest private network operators for the German cable TV network.
Introduction

Bosch Telecom GmbH has an extensive experience in the field of satellite filters. A multitude of filters and multiplexers from L- to Ka-band and frequencies of up to 30 GHz have been designed, manufactured and qualified in various programs in the last 30 years.

Bosch disposes of excellent in-house 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 Bosch Telecom 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 Input Multiplexer Assemblies

Applications

- Communication satellite payloads

Main features

- 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 (8-4 + CD)

- Selfequalized or external equalization
- Very low losses due to high practical Q factor of < 15000 in Ku-band
- Large variety of useful channel bandwidth
- Prediction and controlling of higher modes
- Compact design

Performance

- Compensated waveguide manifold in aluminium, circulator coupling or hybrid coupling in waveguide or coaxial technology
- Compensated filter cavities in thin wall INVAR silver-plated
- Achieved Ku-band IMUX temperature drift of less than 1.2 ppm/K
**Production**

- IMUX assemblies
  (including switches, lowpass filters, hybrids, circulators, isolators ... )
- Single channel filters
- Full RF, mechanical and thermal custom design and layout capability
- Complete in-house environmental test facility
- Powerful RF simulation and optimization software allows final design without breadboard step
- Typical delivery schedule: 6 months

**Heritage**

Major programs:
- DFS Kopenikus,
- Echostar 101/102,
- Koreasat 3,
- Eurasiasat

**Echostar 101/102**
**IMUX assembly**

**Eurasiasat**
**X-band input multiplexer**
Output Multiplexers and Output Multiplexer Assemblies

Application
- Communication satellite payloads
- Combining of high power channels

Main Features
- 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 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 15 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

Performance
- Extremely low loss channel filter design
  \( Q > 12000 \) in C-Band and \( Q > 15000 \) in Ku-Band
- Qualified high power / high temperature design allows band-edge operation of 65 W in C-Band and up to 240 W in Ku-Band
- Unsurpassed thermal stability due to patented temperature compensated channel filters and patented temperature compensated aluminium manifold
- Measured ELFD < 0.4 ppm / K in Ku-band
- Exact fullwave simulation of OMUX and auxiliary components provides extreme high power handling capability and low PIM level designs
- Design verification by test up to 30 kW in Ku-band and 24 kW in C-band
Production

- Complete in-house environmental test facility
- Fully automatic TV Tests
- Extensive in-house high power test facilities incl. ring-resonators up to Ka-band for multipaction, corona, and PIM measurements
- Typical cycle time: < 6 months for assemblies and < 5 months for multiplexer

Heritage

Major programs:
Inmarsat 3, Hotbird 2/4/5,
Intelsat 805/806,
Koreasat 1/2/3,
Echostar 101-104, Telesat,
Sesat, Astra 2B, GE 1A/2A
Diplexers

Receive/transmit band diplexers

Satellite antenna feed systems are generally exposed to extreme environmental conditions as for example temperatures ranging from –120 to +140 degree C. Especially for such applications, Bosch has established a unique high performance diplexer approach for separation of the receive and transmit bands served by one polarisation of a dedicated 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 aluminium silverplated without the need on any tuning to cope with the inherent demands for feed system applications, namely:

- low insertion loss (<0.15 dB)
- good matching properties (>26 dB)
- high receive/transmit band isolation
- flat amplitude and group delay response
- high power handling capability
  - low dissipated power (to facilitate the overall thermal design)
  - high peak power handling (tested up to 12 kW without multipacting)
  - no generation of passive intermodulation products (tested up to –155 dBm)

These outstanding properties have been proved by several diplexers for different programs, as Nahuel, GE.5, Sinosat, Astra 2B, Intelsat KTV.
Filters and Components

Application

- Communication satellite payloads
- Part of higher level integrated subassemblies or standalone units

Astra
Output Filter assembly

Main Features

- Products include ferrite devices, couplers, power combiners and splitters, transitions and low / high power terminations
- Designs available for L, S, C, X, Ku, and Ka bands
- Inhouse developed RF simulation and optimisation software tools provide exact modelling of ferrites, absorbing materials and ceramics
- No breadboarding required
- Low loss and lightweight designs
- High power handling capability at extreme temperatures, multipacting and PIMP-free
- Thinwall aluminium technology incl. EDM and dip-brazing
- Full RF, mechanical, and thermal design and layout capability

Production

- Complete in-house environmental test facility
- Fully automatic TV Tests
- Extensive in-house high power test facilities incl. ring-resonators up to Ka-band for multipaction, corona, and PIM measurements
- Cycle time < 5 months

Heritage

Major programs:
- Intelsat 805/806,
- Echostar 101-104, Eurasiasat,
- Astra 2B, GE 1A/2A

Heritage

Major programs:
- Intelsat 805/806,
- Echostar 101-104, Eurasiasat,
- Astra 2B, GE 1A/2A

Eurasiasat
Input Filter

Antenna
RX/TX

Astra
Coupler
Microwave Switches for Space Applications

Applications:
- Redundancy switch matrices for satellite payloads

Main features:
- Optimum RF performance
- Covering C, X, Ku, Ka band
- C-type and R-type switches
- Single switches, switch blocks and switch matrices
- Random and sequential access actuators with high torque margin
- Magnetically latching in every position
- Mechanically simple design with minimum number of piece parts
- Highest switching reliability
- RF power handling capability up to 1400 W (in Ku band)
- Multipactor and PIMP free
- High level vibration and shock load capability (up to 70 grms)
- Reed switch telemetry

Production:
- Typical delivery schedule: 3 ... 6 months depending on switch type

Technical description:
- Modular design
- Central preloaded ball bearing with dry lubricant
- RF housing and RF rotor machined in one part
- Large gap between rotor and housing for high RF power handling
- Integrated protecting RF windows
- Simple actuator principles

Heritage:
- Fully qualified and delivered for the following major programs: Sesat, Telesat, Echostar 4, Koreasat 3, Intelsat 9, Eurasiasat, Poseidon, Helios 2, Metop, Insat 3, Spot, GE1A/2A, N-Sat
Future Developments

**High temperature superconducting and cryogenic subsystems**
- Receiver Units, Input Multiplexers and filter assemblies with extremely low mass, volume and noise figures
- Output Multiplexers and filter assemblies with extremely low insertion losses, small weight and volume
- Low Phase Noise Oscillators
- Cryogenic Systems

**Electroformed filters and filter arrays**
- Good achievement of predicted RF performance due to extreme accurate design software and better than 5 µm tolerances

**Dielectric filters**
- Tuning free production
- Low cost manufacturing of the negative form
- Extremely lightweight
- Good reproducibility at large quantity
- Mechanical solutions of filter array assemblies

**Cryogenic C-band OMUX with dielectric filters**
- Special dielectric insert design for high practical Q values up to 24000 at Ku-band
- Temperature compensated design
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