51. IWK

Internationales Wissenschaftliches Kolloquium

International Scientific Colloquium

PROCEEDINGS

11-15 September 2006

FACULTY OF ELECTRICAL ENGINEERING AND INFORMATION SCIENCE

INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING - DEVICES AND SYSTEMS, MATERIALS AND TECHNOLOGIES FOR THE FUTURE

Startseite / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=12391

TECHNISCHE UNIVERSITÄT
ILMENAU

Impressum

Herausgeber: Der Rektor der Technischen Universität Ilmenau
Univ.-Prof. Dr. rer. nat. habil. Peter Scharff

Redaktion: Referat Marketing und Studentische Angelegenheiten
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Fakultät für Elektrotechnik und Informationstechnik
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Redaktionsschluss: 07. Juli 2006

Technische Realisierung (CD-Rom-Ausgabe):
Institut für Medientechnik an der TU Ilmenau
Dipl.-Ing. Christian Weigel
Dipl.-Ing. Marco Albrecht
Dipl.-Ing. Helge Drumm

Technische Realisierung (Online-Ausgabe):
Universitätsbibliothek Ilmenau
ilmedia
Postfach 10 05 65
98684 Ilmenau

Verlag: isle
Verlag ISLE, Betriebsstätte des ISLE e.V.
Werner-von-Siemens-Str. 16
98693 Ilrnenau

ISBN (Druckausgabe): 3-938843-15-2
ISBN (CD-Rom-Ausgabe): 3-938843-16-0

Startseite / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=12391

M. Schneider and R. Gehring

Design of a High Power Ku-Band Feed Chain

Introduction

Next generation multimedia telecommunication satellites require an increasing number of telecommunication channels. At the same time often the transmit power per channel increases too. In order to save mass and space combined transmit and receive antennas are preferred. For an effective use of the frequency bands both polarisations have to be used for individual channels. So there is a need for feed chains with a very high power handling capability, especially a very high multipaction threshold, excellent linearity to avoid passive intermodulation products (PIMP) and excellent polarisation decoupling. All components shall be able to work over the full bandwidth of the transmit and receive bands.
This paper addresses the development of a high power Ku-band feed chain that operates in the frequency band 10.7-14.5 GHz. Representative measured results are presented.

Feed Chain Design

The feed chain (Figure 1) consists of a corrugated horn, a circular to square waveguide transition, an orthomode transducer (OMT), a thermal radiator plate and Titanium brackets for the connection to the space craft (s/c).

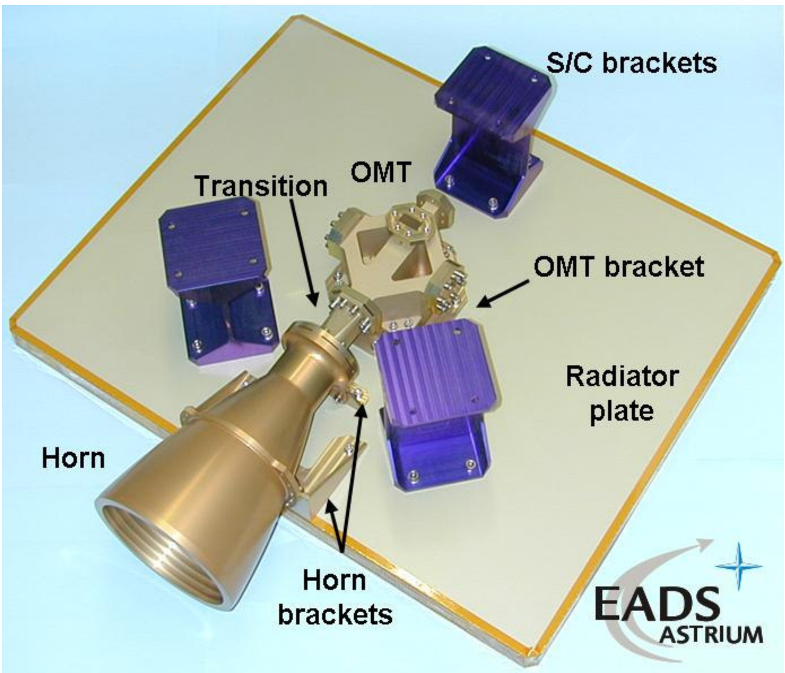

Figure 1 Feed chain with mechanical brackets and radiator plate

The pattern of the corrugated horn was optimised to illuminate either a single offset reflector with a F/D ratio around 1 or the sub reflector of a Gregorian antenna configuration. Optimisation targets were high cross polar discrimination, low return loss, high multipaction threshold, low mass and minimised dimensions. The electrical performance was assessed using TICRA's CHAMP, a program based on mode matching and methods of moments. Figure 2 shows the typical pattern of the feed horn.

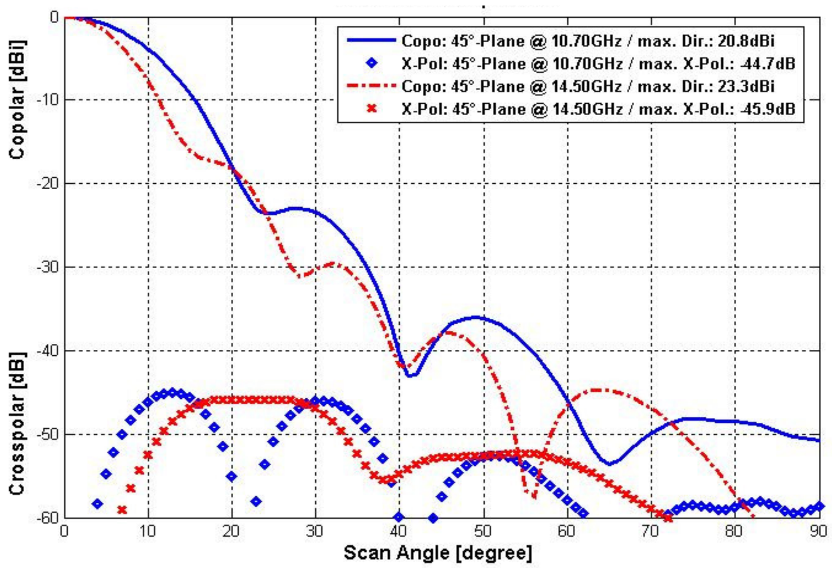

Figure 2 Typical pattern of the feed horn

For the OMT a dual side arm design was chosen. This design provides both, wide bandwidth and high power capability. The electrical performance was assessed using CST Microwave Studio (Finite Integration Technique) controlled by a numerical optimisation program. A combined optimisation target consisting of return loss for both polarisations, isolation between both input ports, cross polarisation and multipaction threshold was chosen. Furthermore the design was restricted to designs with a minimal number of electrical interfaces in order to reduce the number of possible PIM sources. Surface treatment has an important influence on the performance of waveguide components. To investigate the influence of the surface treatment two identical feed chains were manufactured, measured and compared. One has a yellow chromated surface (Immunox) and one a black anodised surface. Figure 3 shows the black feed chain and Figure 4 a comparison of the return loss in the dual side arm for the yellow chromated and the black anodised feed chain.

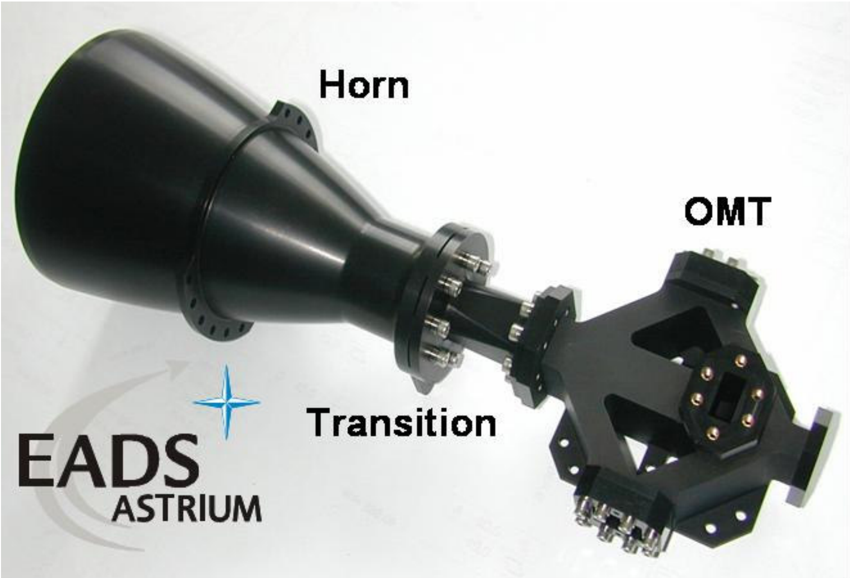

Figure 3 Black anodised feed chain

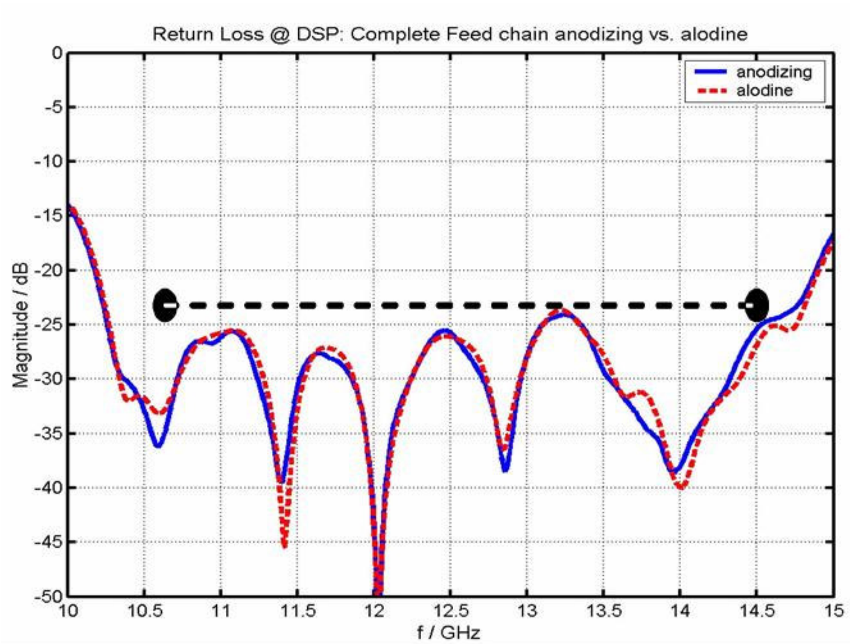

Figure 4 Comparison of return loss of the yellow chromated and black anodized feed chain

The behaviour of black anodised surfaces, especially the secondary electron emission yield (SEY) was investigated at the Universidad Autonoma de Madrid using X-ray photoemission spectroscopy (XPS), scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDM). Additional multipaction samples with silver, yellow chromated and black anodised surfaces were measured at ESA/ESTEC multipaction test facility in Noordwijk. A black anodised surface provides the highest multipaction threshold.[1][2]

Feed Chain Tests

In order to qualify the feed chain for flight programs a full flight test program was undertaken.
Figure 5 shows the pattern measurement in feed test range and Figure 6 a measured radiation pattern of the feed chain.

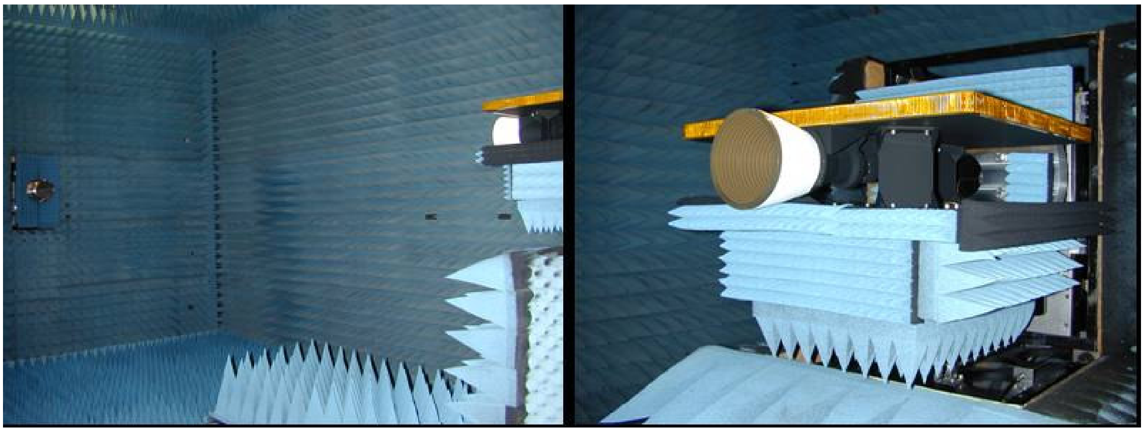

Figure 5 Pattern measurements at Astrium Ottobrunn feed test range

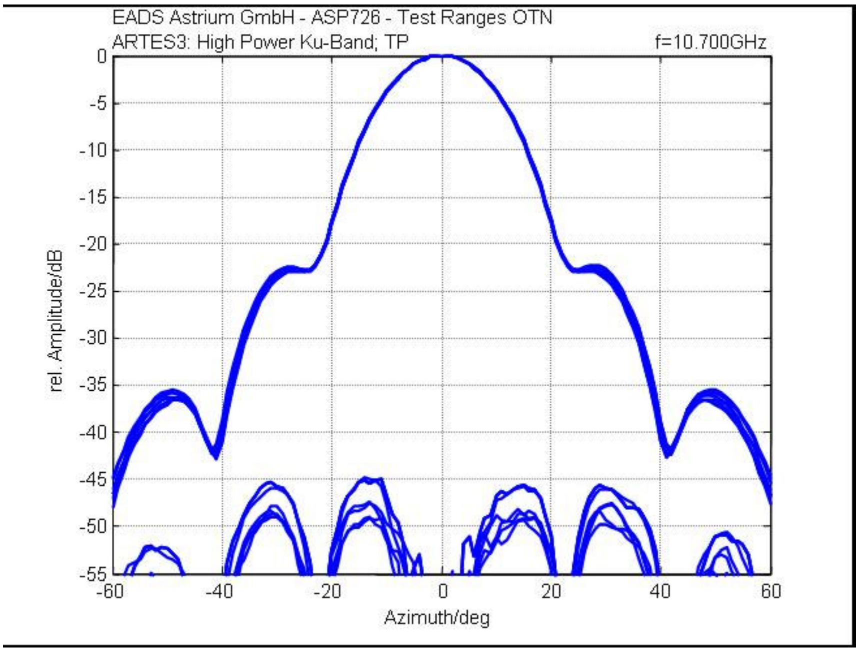

Figure 6 Typical feed chain pattern

A multipaction test was performed using a multi carrier signal with 21 carrier 190W each over a temperature range from -110℃ to +146℃. Figure 7 shows the test set-up in a vacuum chamber at the Astrium Stevenage multipaction test facility. No multipcation was detected.

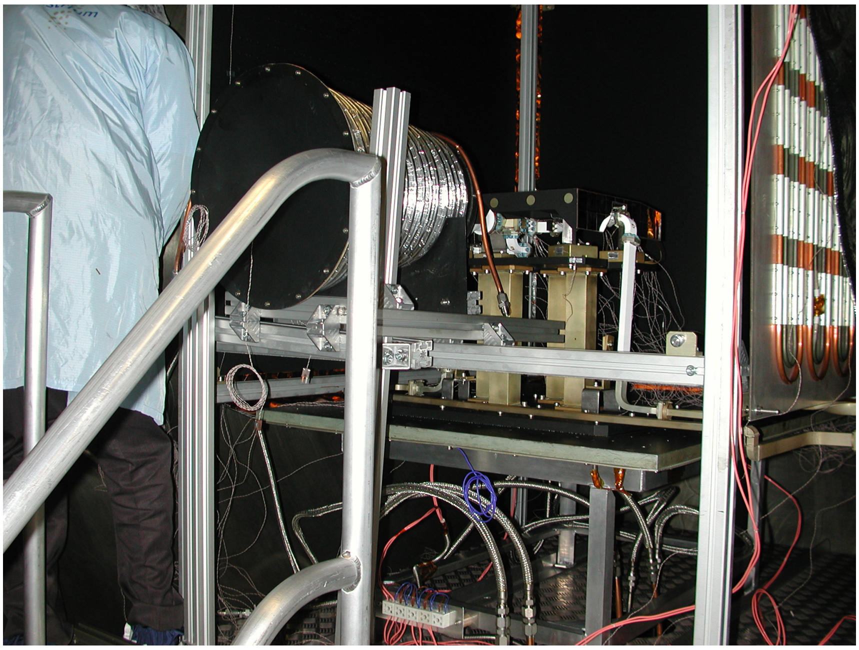

Figure 7 Multipaction test set-up at Astrium Stevenage multipaction test facility

Figure 8 shows the set-up for the thermal PIM test. 3rd order PIM was measured over a temperature range of ±135°C with two 120W carrier as input. The measured 3rd order intermodulation product was below -120dBm over the full temperature range, the 5th order product below the noise floor of -155dBm.

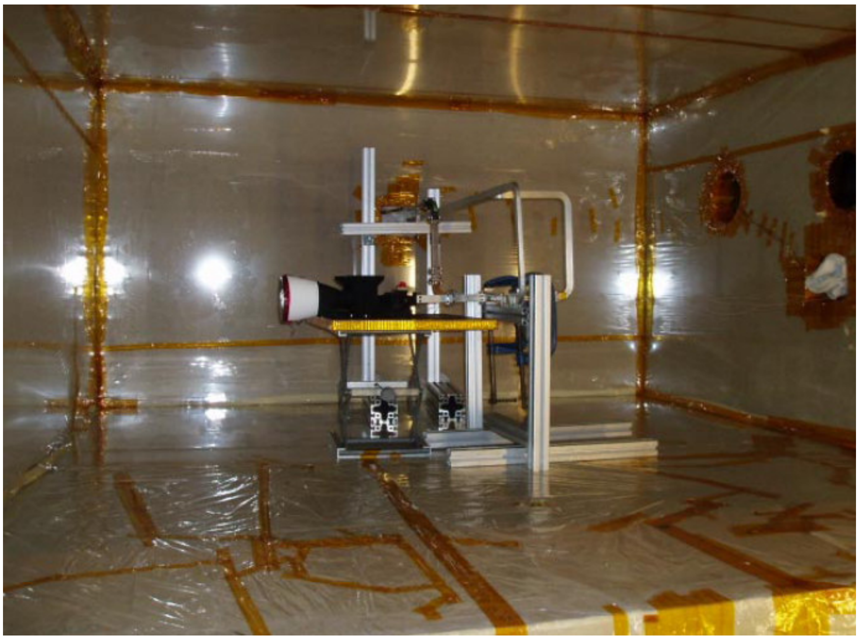

Figure 8 Thermal PIM test at Astrium Stevenage PIM test facility

In order to show that the feed chain will survive the mechanical stress during the launch a vibration test with an equivalent load was undertaken. Figure 9 shows the set-up of the vibration test. The feed chain survived levels of more than 40grms without damages or degradations.

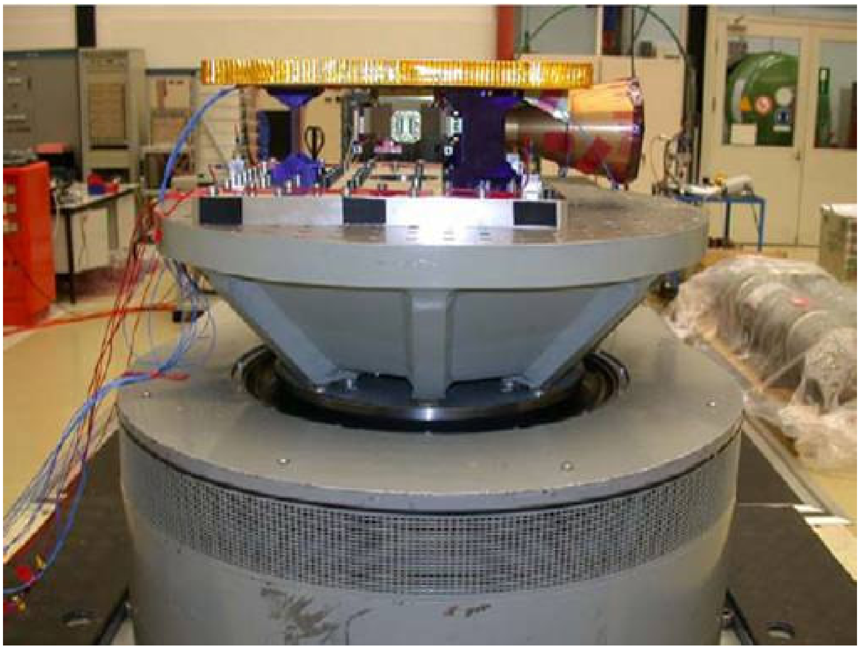

Figure 9 Vibration test at Astrium Ottobrunn vibration test facility

Figure 10 shows the test set-up for the thermal cycling test. The feed chain was cycled 10 times between -150℃ and +146℃. The feed chain has shown no damage or degradation.

Figure 10 Thermal cycling test set-up at Astrium Ottobrunn thermal test facility

The feed chain passed all tests without any damage or degradation and is now qualified for flight programs.

Conclusion and Outlook

A Ku-band feed chain that provides a very high multipaction threshold, low PIM level and an excellent RF performance over a wide bandwidth was developed and fully qualified. Meanwhile the feed chain is used for the satellites Arabsat 4A, Arabsat 4B, Astra 1M, Hotbird 8 and Hotbird 9 and is considered to be used for more flight programs. A new R&D project was started to develop an even more wideband feed chain.[3]

Acknowledgment

The feed chain has been developed under ESTEC Artes 3 Contract No. 17700/03/NL/US. EADS Astrium is grateful to ESA/ESTEC for the support of the development and qualification activities.

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[2] Gehring, R. et al: “PIMP design and test of a Ku band high power feed chain”, 5th International Workshop on Multipactor, Corona and Passive Intermodulation in Space RF Hardware, pp. 195-201

[3] Hartwanger, C. et al: Development on Ku-Band Feed Chains for Satellite Antennas, German Microwave Conference - GeMIC 2006, Universität Karlsruhe (TH), March 28 - 30, 2006

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