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

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
Andrea Schneider

Fakultät für Elektrotechnik und Informationstechnik
Susanne Jakob
Dipl.-Ing. Helge Drumm

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

51st Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
September 11 – 15, 2006

M. Schneider and M. Rayner

Design of a shipborne dual-band reflector antenna

Introduction

Skynet 5 is the next generation of secure global military satellite communications. Under Skynet 5, secure military communication will, for the first time, be delivered in the form of a service provision contract. The contractor is allowed to sell off spare capacity that is not used by the British Armed Forces. For optimal support of the British and Allied Armed Forces, EADS Astrium Limited provides not only the satellites but also the ground support and service [1]. Part of this support is a series of Shipborne Communication Terminals (SCOT) operating in different frequency bands including multi band terminals. This paper addresses the design of a shipborne X- and Ku-band antenna that could be used for communication with Skynet 5 or other military satellites as well as with commercial satellites.

Design Selection

For spacecraft, single or dual offset reflector antennas provide excellent performance but for shipborne antennas, centre-fed axially symmetric antenna configurations are usually required to meet mechanical requirements.
The main disadvantages of using centre-fed antennas are the blockage provided by the subreflector and the back radiation from the subreflector into the horn aperture. The impact of the subreflector can be minimised by careful selection of the antenna geometry and by means of reflector shaping. In order to maximise the gain and to fulfil difficult side lobe requirements, for example [2], shaping of both the main reflector and subreflector is necessary. The antenna design is most usually performed using physical optics analysis (PO) and an optimiser to determine the reflector profiles. However, the numerical effort can be reduced by selection of a reasonable classical axially displaced design, using geometrical optics (GO), as a starting point. Four basic types of axially displaced dual reflector antennas are possible. These can be referred to as: the axially displaced Cassegrain design (ADC), axially displaced ellipse design (ADE), axially displaced Gregorian design (ADG) and the axially displaced hyperbola design (ADH). All four configurations have one ring caustic and one line caustic [3].
The ADC configuration, shown in Figure 1, has a virtual ring and line caustic.

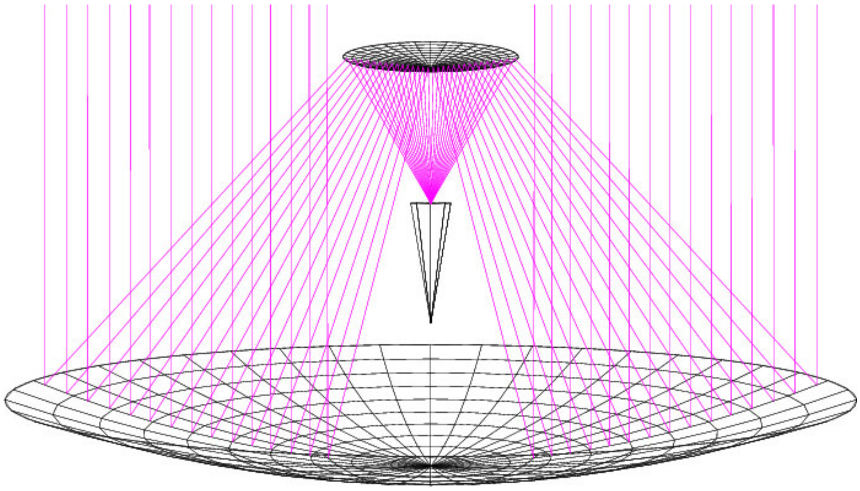

Figure 1 Axially displaced Cassegrain design (ADC)

The most inward ray of the feed horn is redirected by the hyperbolic subreflector to the most inward radius of the parabolic main reflector that is blocked by neither the subreflector nor by the feed horn. The ray from the horn to the rim of the subreflector is redirected to the rim of the main reflector. For large feed horns or where the distance between horn and subreflector is relatively short, the blockage by the horn aperture can become more significant than the blockage by the subreflector. To achieve high efficiencies, the size of the horn aperture, the subreflector and their relative separation need to be balanced.
The ADE, shown in Figure 2, has a real ring and a virtual line caustic.

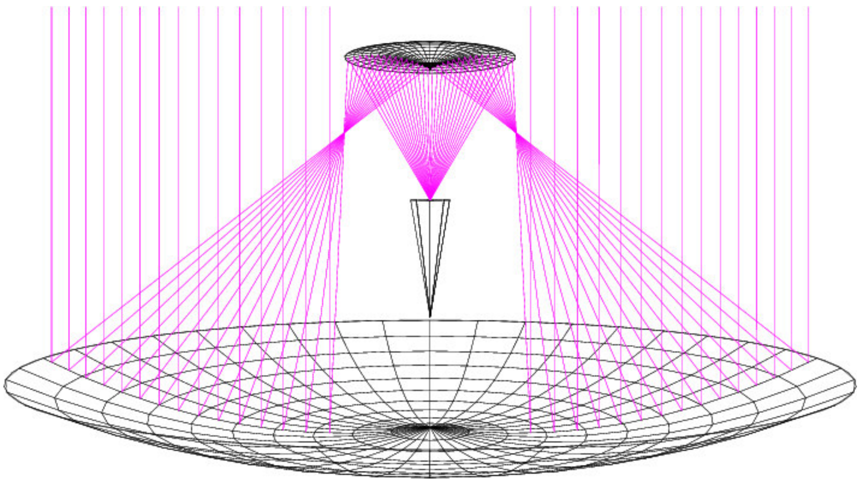

Figure 2 Axially displaced ellipse design (ADE)

The most inward ray of the feed horn is redirected by the elliptical subreflector to the rim of the parabolic main reflector, while the ray from the feed horn to the rim of the subreflector is redirected to the most inward radius of the main reflector that is not blocked by the subreflector. The rays emitted by the feed are inverted meaning that the inner rays of the horn illuminate the outer part of the main reflector and vice versa.
The ADG, shown in Figure 3, has a real ring and line caustic.

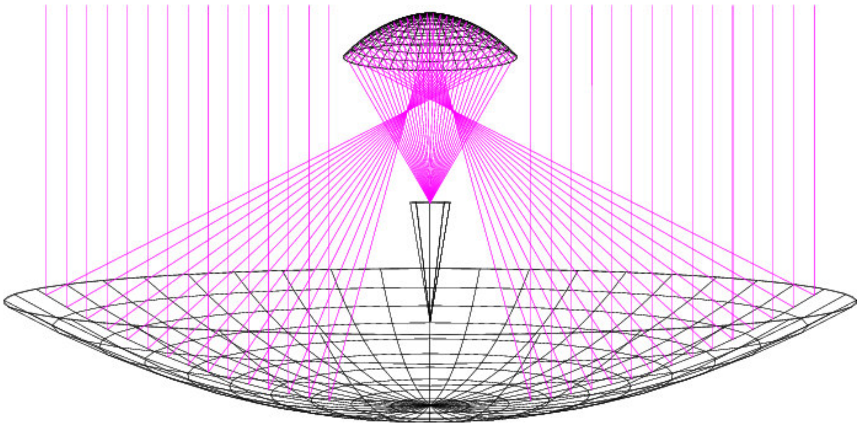

Figure 3 Axially displaced Gregorian design (ADG)

The most inward ray of the feed horn is redirected by the elliptical subreflector to the most inward radius in the opposite half of the main reflector that is not blocked by the subreflector, while the ray from the horn to the rim of the subreflector is redirected to the rim at the opposite half of the parabolic main reflector. For very compact designs (short focal lengths), there is a risk that the outer parts of the subreflector may block the ray path from the inner parts of the subreflector to the outer part parts of the main reflector. The ADH, shown in Figure 4, has a virtual ring and a real line caustic.

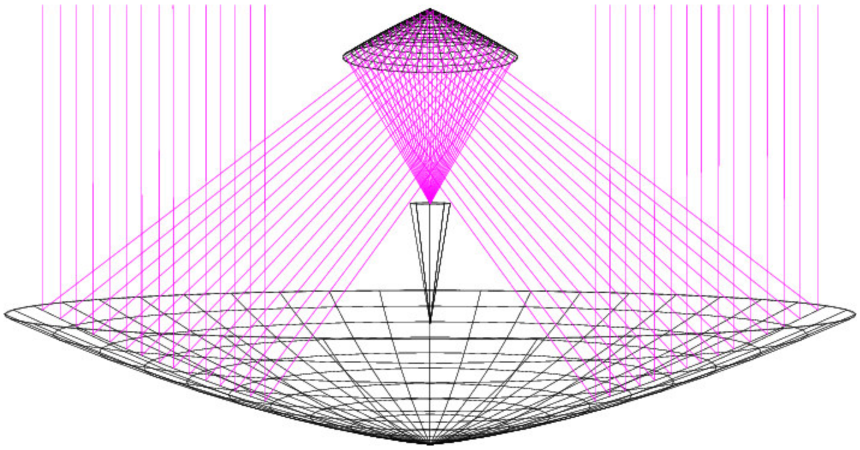

Figure 4 Axially displaced hyperbola design (ADH)

The most inward ray of the feed horn is redirected by the hyperbolic subreflector to the rim in the opposite half of the parabolic main reflector while the ray from the horn to the rim of the subreflector is redirected to the most inward radius in the opposite half of the main reflector that is neither blocked by the subreflector nor by the feed horn. For typical configurations, both blockage by the feed horn and self blockage by the subreflector is a problem for this configuration limiting its use to only certain special cases.

ADE does an inverse mapping, so for the unshaped case the outer part of the main reflector is strongly illuminated. This can lead to higher spillover and high far out side lobes. To reduce the spillover, the subreflector has to be shaped for a more equalised aperture distribution. ADC and ADG do a normal mapping. For the unshaped case, this leads to a relative low aperture efficiency which can be solved by shaping the subreflector for a more equalised aperture distribution. All three configurations, ADC, ADE and ADG offer a good performance. For the numerical optimisation using physical optics, the ADG configuration was chosen.

Feed Components

The antenna shall operate dual circular polarised in X-band and dual linear polarised in Ku-band. So an orthomode transducer (OMT) and a feed horn are needed for Ku-band and an OMT, a polariser and a feed horn for X-band. For best antenna performance, the feed horn has to have axial symmetry, a stationary phase centre and a constant beam shape over the full operating band. These requirements can be met with corrugated horns. Metallic corrugated horns can be designed very fast and accurately using TICRA's CHAMP code that is based on Mode Matching and Method of Moments. For more complicated feeds like dielectric loaded horns, CST Microwave Studio (Finite Integration Technique) can be used. Both CHAMP and CST MWS support file formats that can be used with TICRA's GRASP or POS design and analysis tools for the antenna optimisation. Figure 5 shows the corrugated X-band feed horn, Figure 6 the return loss of the horn and Figure 7 a typical horn pattern.

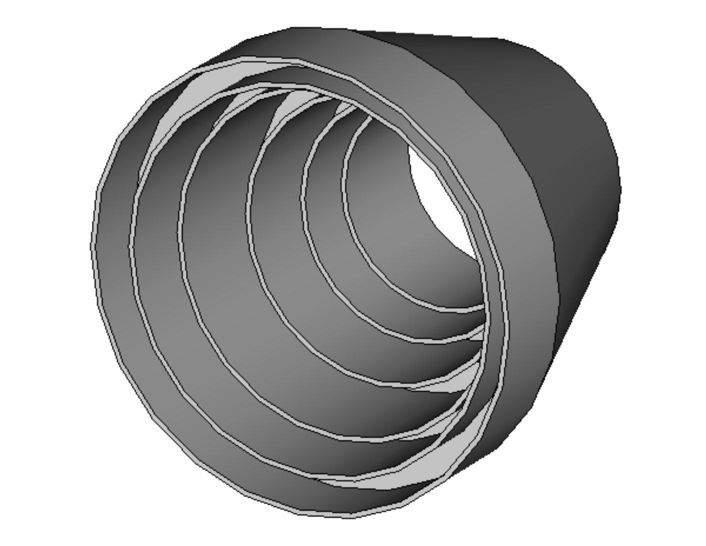

Figure 5 Corrugated feed horn for X-band

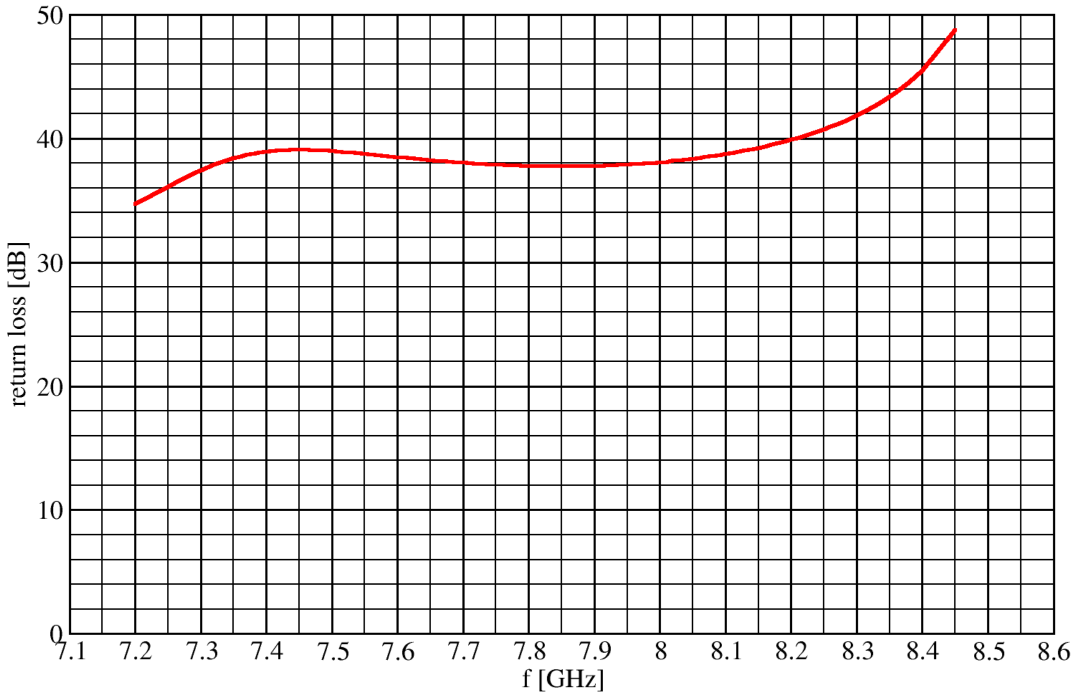

Figure 6 Return loss of the X-band horn

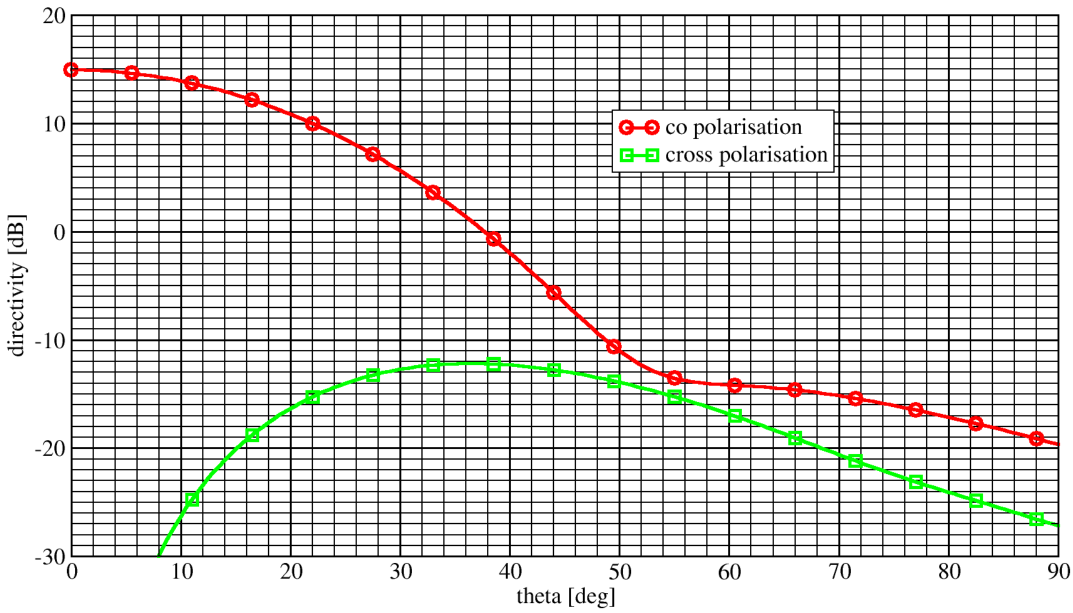

Figure 7 Typical pattern of the X-band horn

The polariser has to provide a low axial ratio and return loss. A corrugated polariser with circular cross section was chosen (Figure 8). The polariser was analysed and optimised using CST Microwave Studio. Figure 9 shows the return loss and Figure 10 the axial ratio of the polariser. A very low axial ratio over the full X-band was achieved.

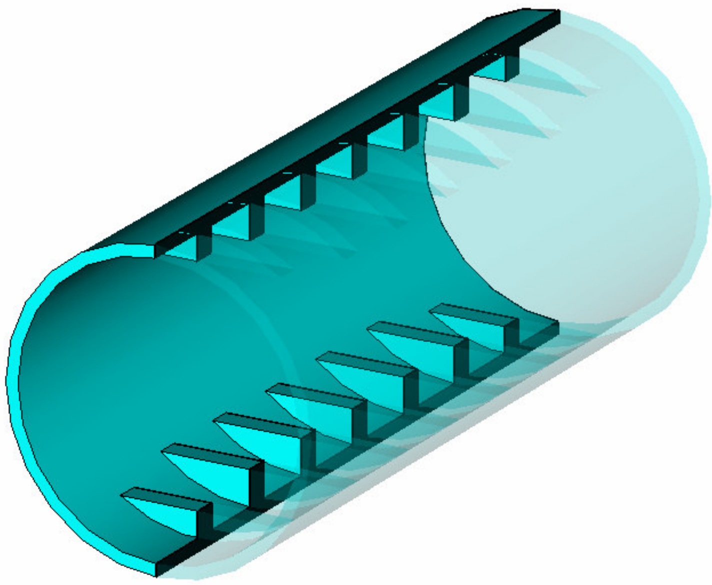

Figure 8 Corrugated polariser

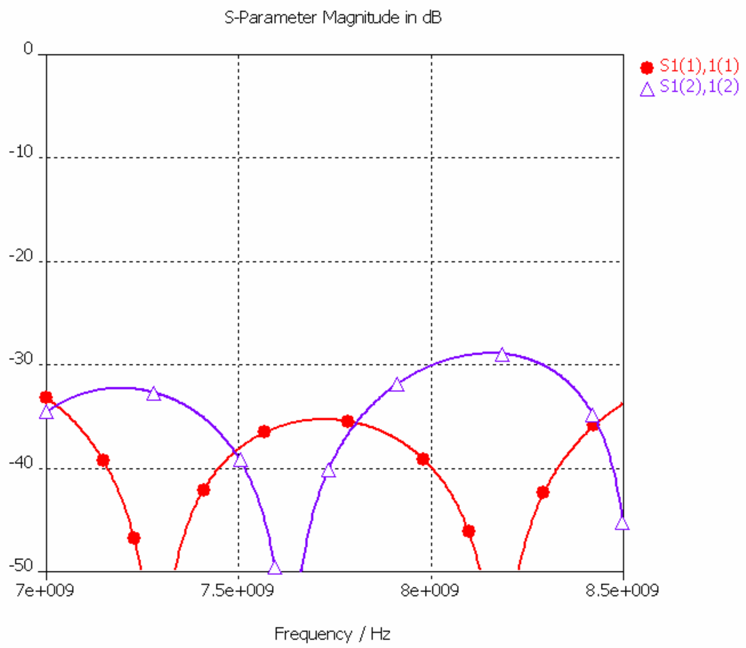

Figure 9 Return loss of the corrugated polariser

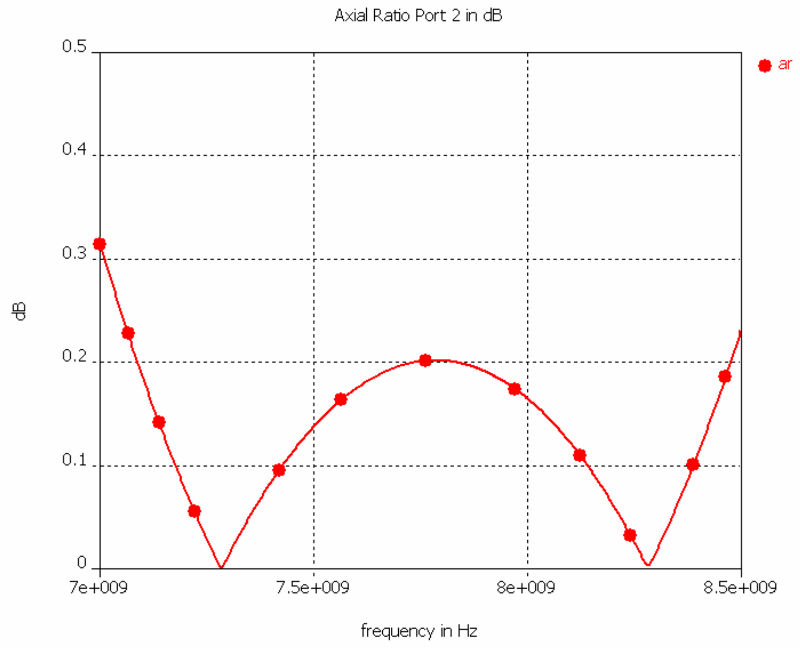

Figure 10 Axial ratio of the corrugated polariser

The antenna operates using one polarisation for transmit and the orthogonal polarisation for receive. An OMT is used to separate or combine the polarisations. It needs to have a low return loss and a high decoupling between the orthogonal ports. A single side arm OMT was chosen. Figure 11 shows the Ku-band OMT. The through port is used for the receive band (10.95-12.75GHz) and the side port for the transmit band (13.75-14.50GHz). Return loss and isolation of the OMT is shown in Figure 12. A low return loss for the through port in the Rx-band and for the side port in the Tx-band as well as a high isolation between through and side port was achieved.

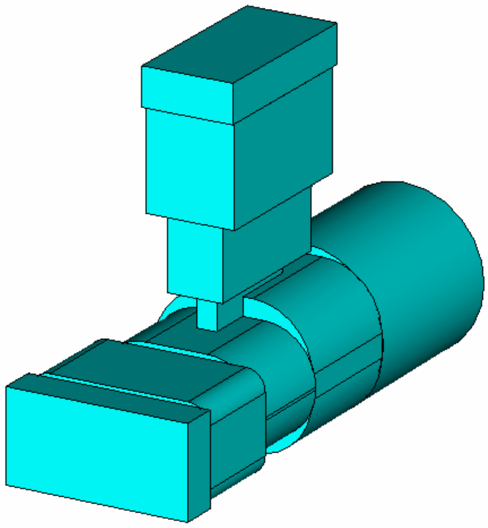

Figure 11 Ku-band OMT

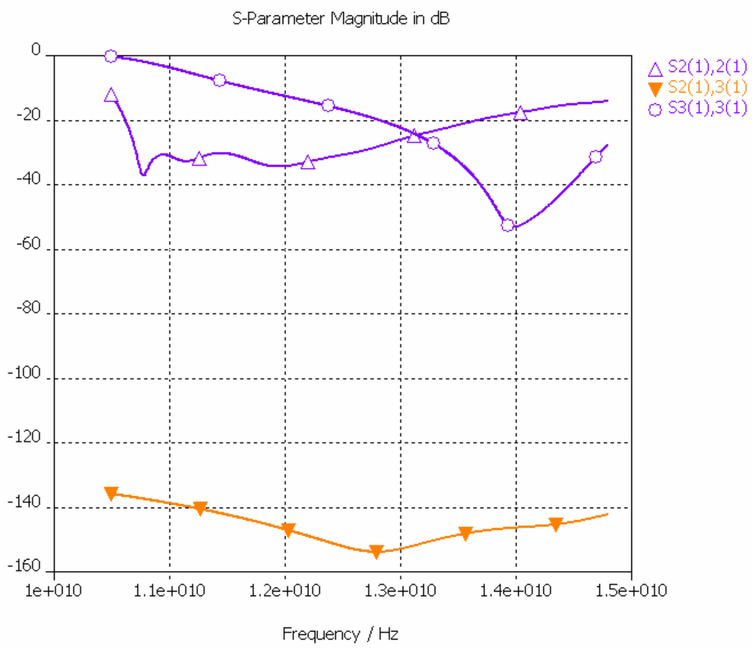

Figure 12 Return loss and isolation of the Ku-band OMT

Antenna performance

The antenna design requires a complex optimisation approach using Finite Integration Technique, Mode Matching and Method of Moments for the feed chain components and Physical and Geometrical Optics for the reflector shaping. The radiation pattern of the feed chain was expanded into spherical wave coefficients and used as the source for the antenna system. The performance of the feed chain was considered in loss, cross polar and axial ratio budgets. The main reflector has to be shaped to work in both X- and Ku-band, only the feed chain and subreflector will be replaced if the band is changed.
Figure 13 shows the pattern of the antenna at 7.75GHz for circular polarisation and Figure 14 at 13.75GHz for linear polarisation. In both X- and Ku-band the antenna provides a high gain and very low far out side lobes.

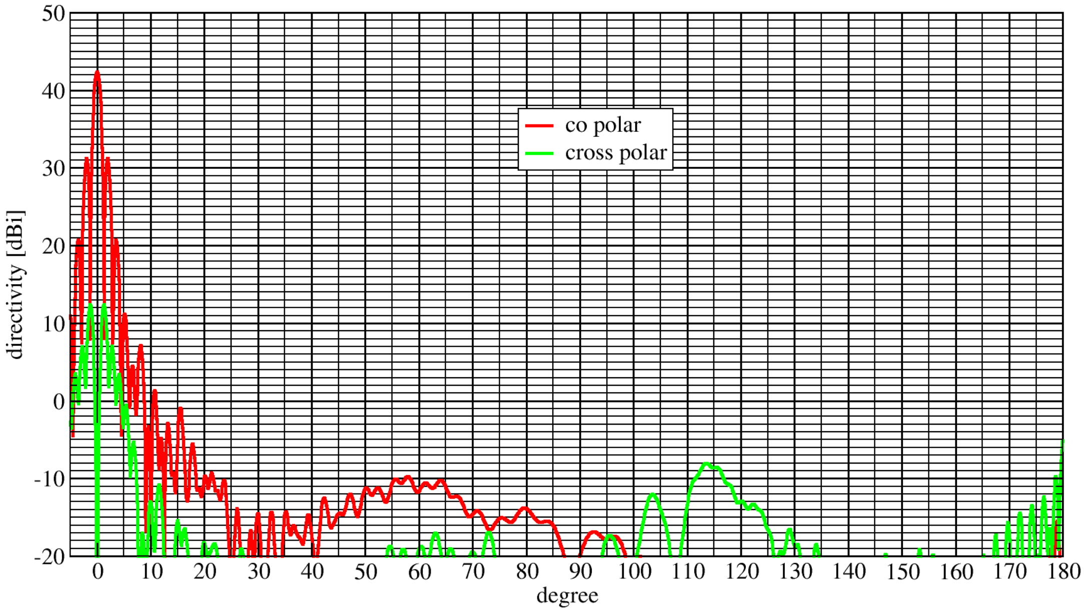

Figure 13 Antenna pattern at 7.75GHz

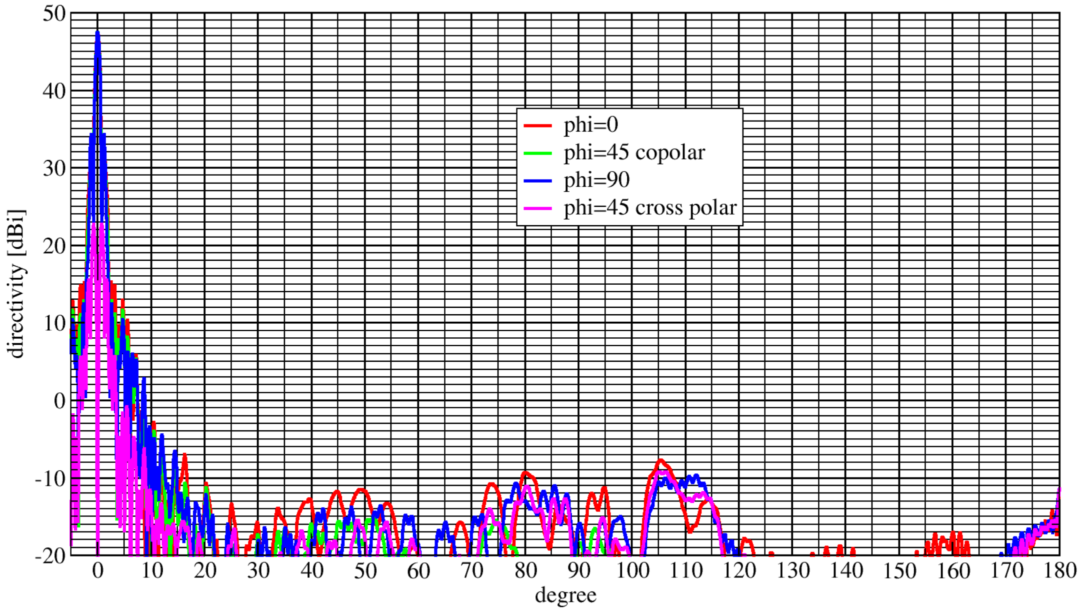

Figure 14 Antenna pattern at 13.75GHz

Summary

A dual-band centre-fed shipborne antenna that could be used for both military and commercial satellites was designed using a combination of Finite Integration, Mode Matching, Methods of Moment and Geometrical and Physical Optics. A high gain, very low far out side lobes and low back radiation from the subreflector into the feed horn were achieved by means of shaping both the sub and main reflector of an axially displaced Gregorian antenna design.

References:

[1] http://www.paradigmsecure.com/

[2] Eutelsat Standard M EESS502 Issue 9 Rev. 1

[3] F. J. S. Moreira and A. Prata, Generalized Classical Axially Symmetric Dual-Reflector Antennas, IEEE Transactions on Antennas and Propagation, Vol. 49, No. 4, April 2001

Authors:

Dr.-Ing. Michael Schneider
Dr. Mark Rayner
EADS Astrium Ltd., Gunnels Wood Road, Stevenage
SG1 2AS, United Kingdom
Phone: +44 1438 77 3233
Fax: +44 1438 77 4372
E-mail: michael.schneider@astrium.eads.net