Dual Offset Shaped Reflectors Optimized for Gain and XPD performance

Hans-Henrik Viskum* & Stig Busk Sørensen
TICRA, Copenhagen
Denmark

1. Introduction. Contoured beam antennas may conveniently be designed by shaping the reflector surface to produce a gain pattern which closely resembles the prescribed coverage area. The most appropriate technique is based on using physical optics (PO) to calculate the far-field pattern and optimize, using a minimax scheme, the surface shape until the desired performance is obtained . For most contoured beams the gain performance is of primary importance, and so it usually suffices to employ single-reflector systems which are fairly simple and thus attractive from a manufacturing and implementation point of view. However, if the antenna system is to operate in linear polarization with a stringent requirement on the polarization purity, it may be necessary to adopt polarization sensitive gridding of the reflector, or use a dual reflector configuration in which the cross polarization may be reduced by appropriately tilting the main- and sub reflector with respect to the feed. This paper presents the design of a dual offset reflector antenna for a typical European coverage divided into three regions with different gain requirements and a cross polar discrimination (XPD) constraint of 33 dB. The shaping is described in some detail and a comparison is made between designs optimized with and without XPD constraints.

2. Service requirements. The coverage is shown as three polygons in Figure 1. The relative directivity requirements are 0, -1 and -3.5 dB as indicated in the figure, and the XPD is required to be better than 33 dB in all three service areas over the frequency range 10.7-11.7 GHz.

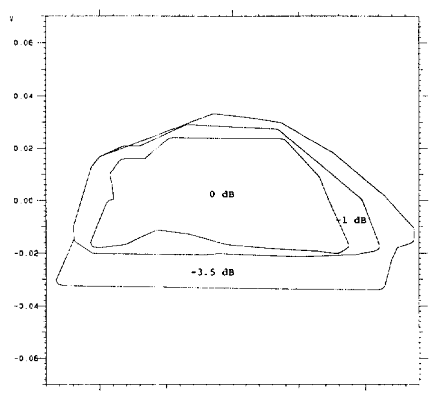

Figure 1. Definition of European coverage regions with relative directivity requirements indicated.

0-7803-2009-3/94/$4.00 © 1994 IEEE.

The antenna system must operate in dual linear polarization corresponding to the feed polarization being in the plane of offset (x-polarization) or orthogonal to this plane (y-polarization). The XPD is defined as the difference between the copolar field and the cross polar field for each feed orientation.

It is worthwhile to emphasize the challenge in these requirements: to provide an XPD of 33 dB in the low-gain region where the copolar directivity may typically be around 26 dBi, implies that the cross polar component must be below -7 dBi to be compliant. This is in the order of 40 dB below copolar peak, and an interfering signal 54 dB below peak will change the XPD as much as 2 dB. The software used to design a system with these requirements must therefore be extremely accurate and take into account all predictable effects in the analysis, e.g. sub- and main reflector diffraction, frequency sensitivity, feed near field effects and phase center movement with frequency. If furthermore a real feed chain consisting of horn and OMT exists and measurements are available, these should be used in the antenna synthesis. Finally, the hardware verification requires a very accurate antenna test range.

3. Antenna design. The feed by choice in a dual offset system is a corrugated horn. At the early design stage measured feed data are rarely available, and thus we model a corrugated horn by a point source located in complex space. This representation of a Gaussian beam has the advantage that it models near-field effects extremely well, and has been implemented successfully in many of TICRA's software packages.

The final optimization of the reflector surface has been performed using the POD program developed at TICRA, in which both reflectors are represented by expansions in Zernike polynomials, and PO is used on both sub and main reflector. A minimax routine determines the Zernike expansion coefficients such that the minimum gain and XPD requirements are fulfilled to the greatest possible extent. However the minimax optimization must be started with an initial reflector geometry. If the desired aperture shape is circular it is usually a good choice to select a compensated system consisting of conic sections, either in a Cassegrainian or Gregorian configuration which are conveniently expressed in Zernike series with only a few coefficients. A slight amount of defocusing can be applied to the main reflector to prevent any part of the coverage area being outside the main beam region of the initial system.

In the present example the coverages are slightly elliptical. Taking advantage of this makes it possible to reduce the aperture area by employing an elliptical main reflector. However, an initial configuration of conic sections is now less appropriate, and it may take significantly longer to obtain convergence with POD. Instead, a geometrical optics (GO) based program DORELA is employed to produce an initial system with elliptical main reflector and an aperture field which, according to ray optics, has uniform phase and a prescribed aperture taper.

The maximum number of Zernike modes needed to represent the reflector in the PO optimizations is determined from the reflector diameter size and the extent of the aperture. Higher order modes produce many ripples over the reflector surface, having the effect of radiating towards the sidelobe region. For the present design we have used up to fourth order modes in the azimuthal direction for main and sub reflector, and up to 5 modes in radial direction.

An optimization in which the XPD is not considered is made first, resulting in the directivity performance shown in Figure 2 (a) and XPD in Figure 3 (a). Next an XPD constraint of 33 dB is imposed, a simple extension to the POD program due to the great versatility, leading to the results presented in Figures 2 (b) and 3(b).

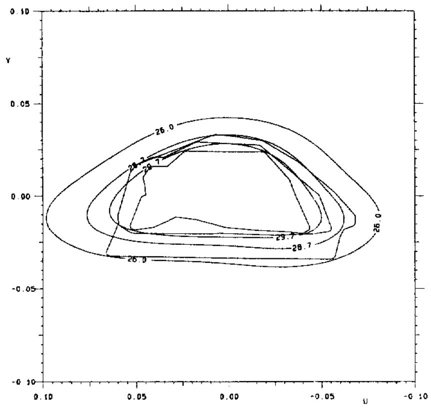

Figure 2 (a). Copolar gain contours for POD optimized design without XPD constraints.

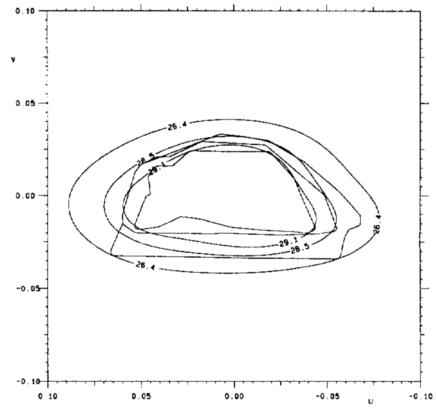

Figure 2 (b). Copolar gain contours for POD optimized design with XPD constraints.

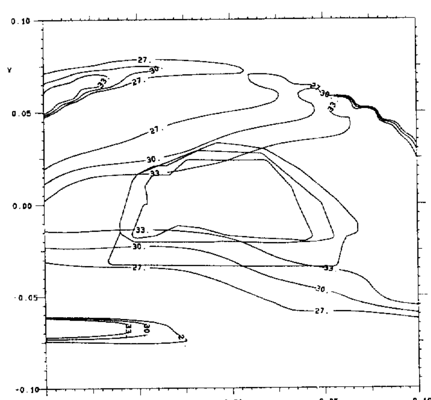

Figure 3 (a). XPD at 11.7 GHz for POD optimized design without XPD constraints.

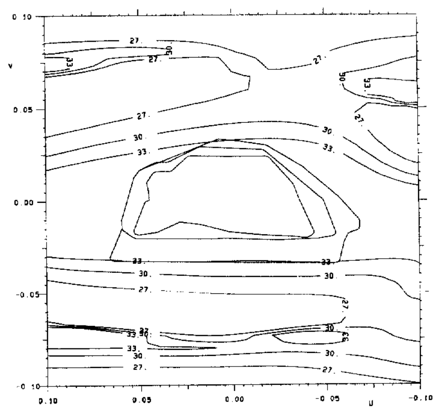

Figure 3 (b). XPD at 11.7 GHz for POD optimized design with XPD constraints.

It is seen that the XPD is significantly improved from worst-case values of 27 dB to better than 33 dB. This is achieved at the expense of 0.6 dB and 0.2 dB of copolar gain at the inner and middle coverages, respectively, whereas the minimum directivity at the outer coverage is actually improved to a minimum of 26.4 dBi. This demonstrates how the optimization improves the XPD both by reducing the cross polarization and by increasing the copolar gain. The small gain reduction at the inner coverages is usually acceptable since it may be compensated through an increase in transponder power, whereas there is no similar way to remedy a poor XPD.

4. Conclusions. It has been shown that by incorporating XPD constraints into a general PO optimization program POD, it is possible to improve the cross polar performance of a dual reflector system at the expense of copolar gain. Such capability is extremely useful since any shaping applied to a dual reflector system, even when initially compensated by choice of geometry, will usually degrade the cross polar performance. The POD program has proven a versatile tool into which the XPD constraint was easily incorporated, and yields a high degree of confidence in the obtained results due to the accuracy of the prediction method which involves PO analysis of both main and sub reflectors. The feed is modelled as a Gaussian beam including near-field effects on the sub reflector illumination. POD furthermore has the feature that once measured data for a real feed chain are available, they can be input to the program in the form of spherical wave coefficients, thereby accounting fully for the true performance of the feed system.

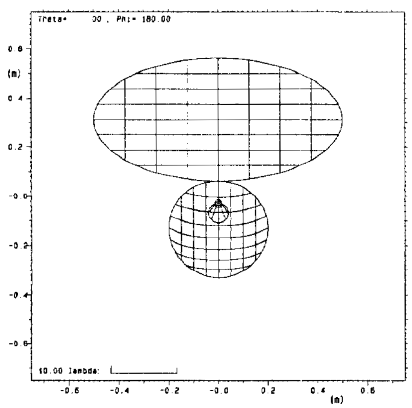

Figure 5 (a). Shaped reflector system, front view

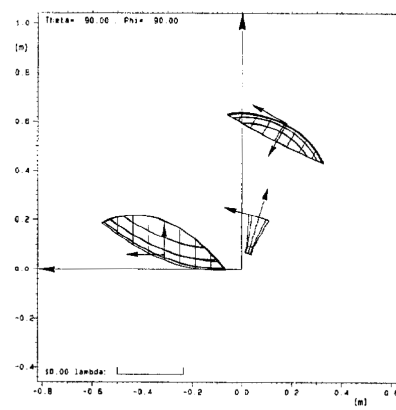

Figure 5 (b). Shaped reflector system, side view