REFLECTARRAY FOR K/KA-BAND TERMINAL ANTENNA

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INTRODUCTION

Different satellite systems have been defined to provide broadband communications and internet access in remote geographical areas in Ka band (20-30 GHz) [1-2], being the up-link at 30 GHz and the down-link at 20 GHz. Cost-effective antennas are required for fixed and portable terminals in Ka-band. Conventional reflectors are a preferred option to maintain reduced costs. However, the different receive (Rx) and transmit (Tx) frequencies obliges to use either a dual-frequency horn or two independent horns. The dual-frequency horn presents some difficulties, mainly because the phase-centre is different at each frequency, which would cause a reduction of the antenna gain. The use of independent feeds for Tx and Rx is simpler, but this solution is not possible using reflector antennas, because the two horns located at different positions cannot generate a beam in the same direction.

When the transmission and the reception links are in orthogonal linear polarisations, a reflectarray can be designed with two independent feeds, one at 30 GHz for the up-link and another at 20 GHz for the down-link, by adjusting the dimensions of the patches independently for each polarisation and each beam.

A reflectarray antenna consists of an array of elements printed on a grounded dielectric substrate, in which the phase of the reflected field is adjusted in each element to focus a beam when it is illuminated by feed. The adjustment of phase in each element can be made in different ways, being one of the most usual one the variation of the resonant length of the printed elements [3]. A unit cell of reflectarray with two stacked rectangular patches is shown in Fig. 1. The configuration with two layers of patches allows to obtain a larger bandwidth, as demonstrated in [4].

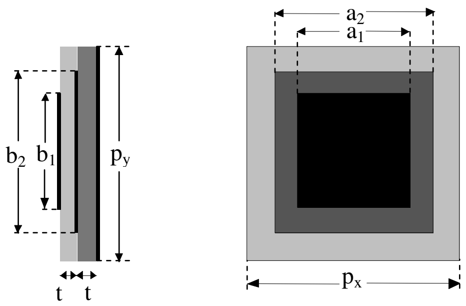


Fig. 1. Unit cell of a two-layer reflectarray

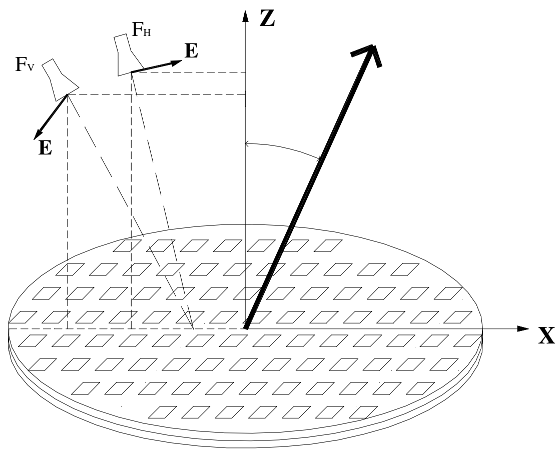


Fig. 2. Reflectarray with two independent feeds

This contribution describes the design, manufacturing and test of a printed reflectarray for Ka-band terminal antenna. The antenna is designed for linear polarisation, Vertical for transmitting (Tx) and Horizontal for receiving (Rx). The reflectarray has been designed to produce a focused beam at 30 GHz (uplink) in V polarisation and also at 20GHz (downlink) in H polarisation, by an independent optimisation of the patch dimensions for each frequency and each polarisation, as described in [5].

ANTENNA DESIGN

The dimensions of the reflectarray panel have been chosen as 18-cm x 18-cm to provide a gain of 30 dBi in K band and 33 dBi in Ka-band. Two separate feeds are used to illuminate the reflectarray for H (20 GHz) and V polarisation (30 GHz), see Fig. 2. Standard pyramidal horns (15 dB) from Narda have been used as feed (Ref. 638 for 20 GHz and Ref. V637 for 30 GHz). The radiation pattern of these horns have been modelled as a $\cos^q(\theta)$ function, with a factor q=10.5 at 20 GHz and q=10.7 at 30 GHz. The position of each feed is defined by of the coordinates in mm of its phase centre with respect to the reflectarray centre, see Fig 2. The K-band horn is placed at coordinates (- 85, 0, 180) with its axis pointing towards the point (- 15.9, 0, 0), whereas the Ka-band horn is located at coordinates (- 40, 0, 195) and oriented towards the point (-5.62, 0, 0). The periodic cell was defined as 5-mm x 6-mm to avoid the appearance of grating lobes. In spite of the different positions of the horns, the reflectarray is designed to radiate a beam in the direction of 20º with respect to z-axis, for the two bands. To do that, the reflectarray must introduce the phase-shift distribution shown in figure 3.a at 20 GHz for H-polarisation (with the electric field on the direction of x-axis), and the phase shown in figure 3.b at 30 GHz for V-polarisation (with the electric field on the direction of the y-axis).

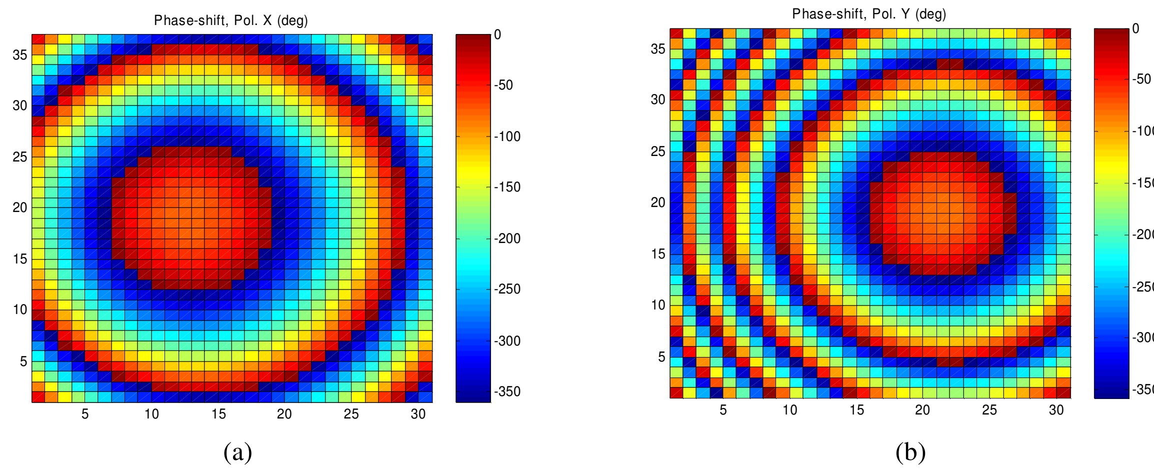


Fig. 3. Phase-shift distribution to be implemented on the reflectarray. (a) at 20 GHz for H-polarisation. (b) at 30 GHz for V-polarisation.

The reflectarray element is made of two stacked varying-sized patches, because it provides a good element bandwidth for both frequencies. The reflectarray was designed by adjusting the horizontal dimensions of the patches to focus the beam at 20 GHz, and the vertical dimensions for the 30-GHz beam, following the design technique described in [4-5]. The reflectarray analysis is based on Spectral-Domain Method of Moments assuming local periodicity.

The patches are printed on a commercial substrate (CuClad 233LX) of thickness 0,787 mm, relative dielectric constant εr= 2.33 and loss tangent, $\tan\delta$ = 0.0012. The two layers are bonded by a bonding film 37-micron thick (εr= 2.32 and $\tan\delta$ = 0.0012). The reflectarray was designed by using an iterative routine that adjusts the dimensions of the patches in each reflectarray element by calling the analysis routine until the required phase at each frequency and polarisation is achieved. In the process, the dimensions (a_1, a_2) are adjusted to achieve the phase distribution shown in figure 3.a at 20 GHz and (b_1, b_2) are adjusted to achieve the phase distribution shown in figure 3.b at 30 GHz. Note that this independent adjustment of the phase for each polarisation cannot be achieved by using conventional reflectors.

Once the dimensions of all the patches are obtained, the radiation patterns and antenna gain have been computed at different frequencies. A 10% bandwidth is obtained for a reduction in gain of 0.6 dB in Ka-band and 0.4d B in K-band with respect to the maximum. The estimated antenna efficiency is 65% at 30 GHz and 70% at 20 GHz.

RESULTS

The demonstrator has been manufactured, including a supporting structure that ensures the correct position of the two feed-horns, see figure 4. The printed arrays are manufactured by using conventional photo-etching techniques, and the two layers are bonded using a curing process. The radiation patterns and antenna gain have been measured in anechoic chamber. The measured 3D patterns in directivity (dBi) are shown figure 5.a at 20 GHz. The cross-polarisation component in dBi is also shown in figure 5.b. Co- and cross-polar measured components at 30 GHz are shown in figure 6. Note that cross-polarisation is very low in the region of the main lobe (40 dB below the maximum).

The comparison between measured and simulated radiation patterns in gain in the principal planes are shown in figures 7 and 8. These figures show a very good agreement between the measurements and simulations in both frequency bands.

The antenna gain has been measured by comparison with a standard horn in the pointing direction (θ=20º, φ=0º). Therefore the reduction in gain produced by beam squint is taken into account in these measurements. The results show that the gain is very stable in both bands. The measured gain is 30.03 dBi at 20 GHz and 32.91 dBi at 30 GHz. These values represent an antenna efficiency of 70% at 20 GHz and 62% at 30GHz. The gain varies between 29.4 and 30.5 dBi in the frequency range 18-22 GHz, and from 32 to 32.91 dBi in the 27.4-31.4GHz frequency band. This bandwidth is sufficient for the terminal Ka-band antenna.

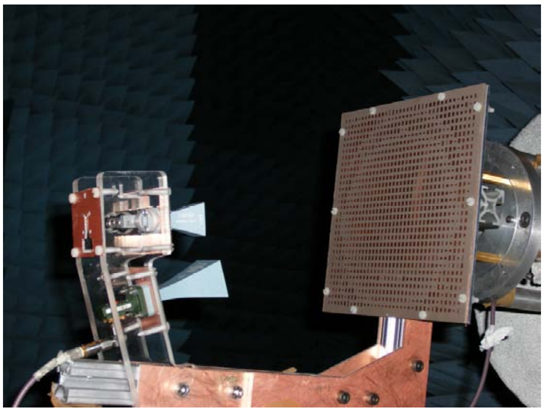
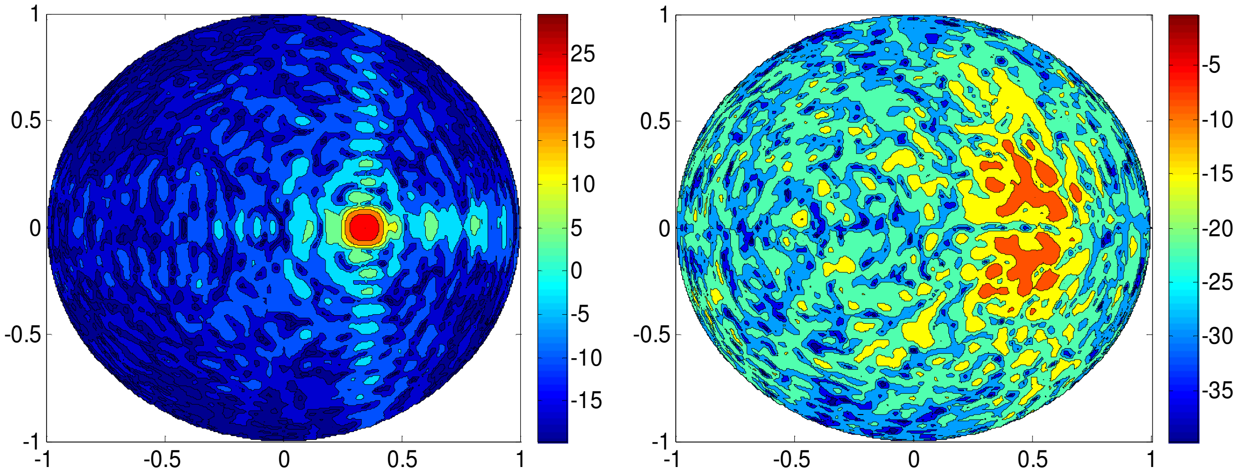
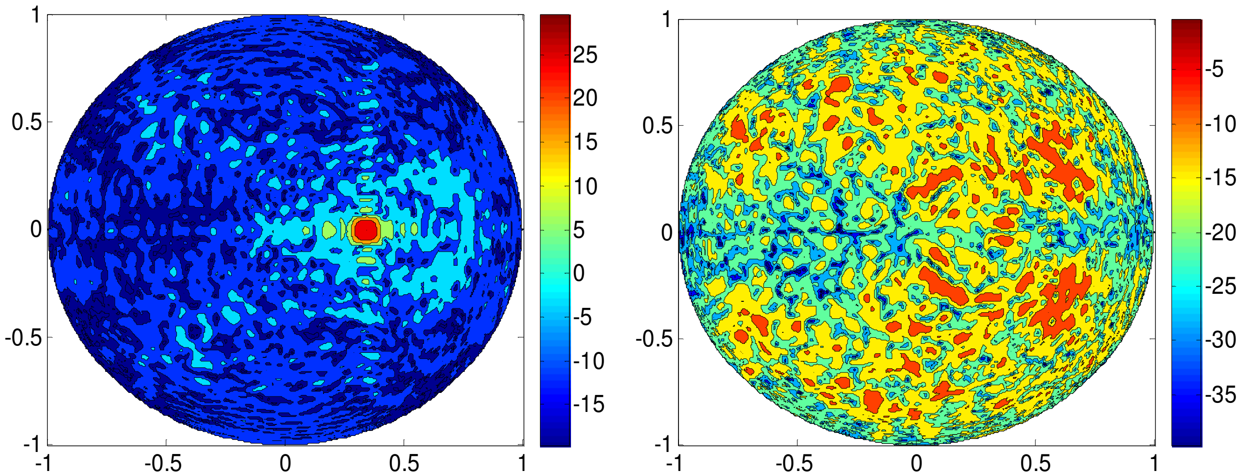


Fig. 4.Prototype



(a) (b)

Fig. 5. 3D directivity measured patterns (dBi) at 20 GHz. (a) co-polar directivity, (b) Cross-polar component.

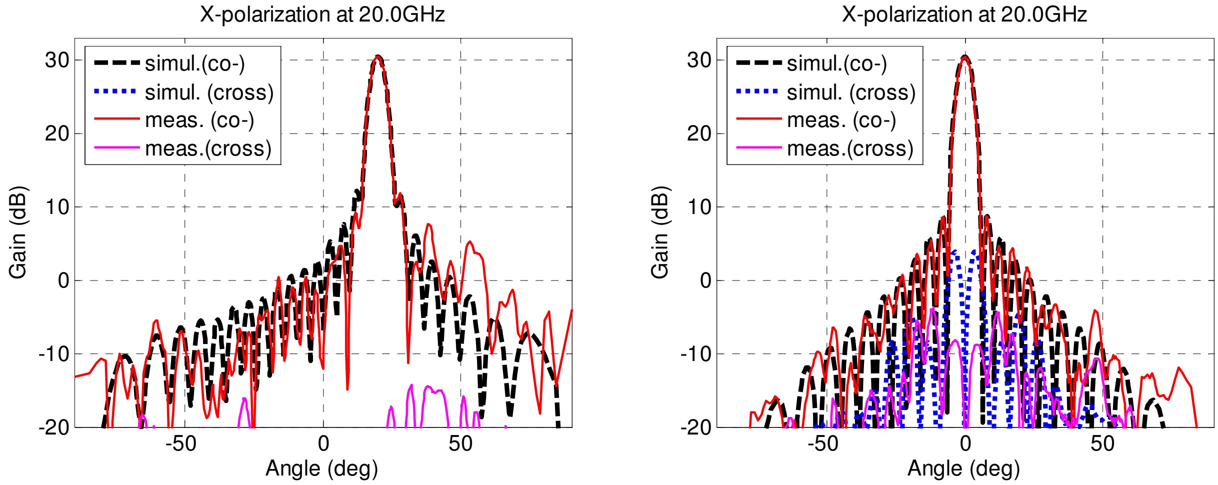


(a) (b)

Fig. 6. 3D directivity measured patterns (dBi) at 30 GHz. (a) co-polar directivity, (b) Cross-polar component.

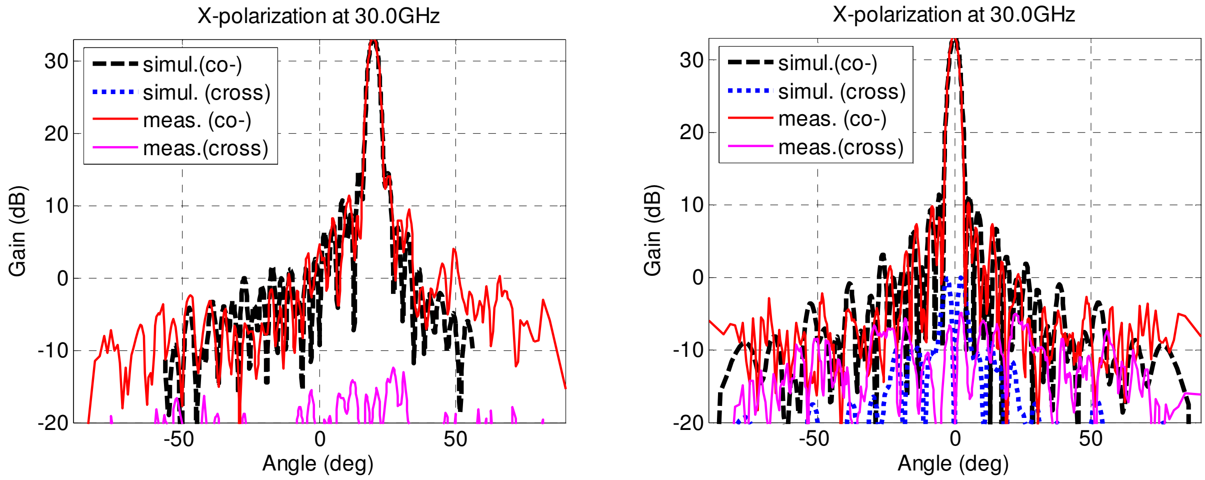
CONCLUSIONS

An 18-cm reflectarray terminal antenna in K/Ka-band has been designed, manufactured and tested. The measured radiation patterns show an excellent behaviour in a frequency band larger than a 10% for both reception and transmission bands. The measured antenna gain is 33 dBi at 30 GHz and 20 dBi at 20 GHz, having an antenna efficiency very similar as conventional reflectors. These results show that the reflectarray technology can be an alternative for terminal antennas in Ka band.



(a) (b)

Fig. 7. Comparison of measured and simulated gain radiation patterns in the principal planes at 20 GHz. (a) On XZ plane, (b) on the plane forming an angle of 20 degrees with YZ plane.



(a) (b)

Fig. 8. Comparison of measured and simulated gain radiation patterns in the principal planes at 30 GHz. (a) On XZ plane, (b) on the plane forming an angle of 20 degrees with YZ plane.

ACKNOWLEDGEMENT

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