Prototype of a compact mechanically steered Ka-band antenna for satellite on-the-move

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***Abstract*—We present a functional prototype of a SOTM user terminal antenna based on a planar offset Fresnel lens that implements a new mechanical steering concept previously proposed by the authors. The beam scanning is achieved by in-plane translation of the feed (for zenith scanning) and axial rotation of the antenna (for azimuth scanning). The feed is as assembly of a circular polarization patch and a small planar lens. The goal of the small lens is two-fold: to adjust the primary feed directivity for a proper illumination of the main lens and to shift backwards the phase center of the patch, allowing reducing the antenna height. In the developed prototype the measured gain is 27 dBi at 30 GHz with a scan loss of 3 dB for an elevation scanning range between 18º and 53º for full azimuth. The antenna provides good circular polarization, with a cross polarization level below -14 dB. The side lobe level is below -10 dB for all beams positions. The antenna weight is less than 500 grams.**

Keywords—Flat lens, frequency selective surface (FSS), circular polarization, wireless communication network, satellite-on-the-move (SOTM)

I. Introduction

Mobile broadband access thought Ka-band satellite systems has a great potential market. The antenna design for mobile terminals is one of the main challenges. These antennas must be compact, have high gain and wide scanning coverage. Circular polarization is another common requisite. Moreover, simple low-cost solutions are required to allow mass production. Mechanical steering can reduce significantly the antenna costs but usually implies bulkier devices when compared to phased arrays [1]. In [2] we presented a planar antenna design with wide elevation scanning coverage obtained by in-plane translation of the main planar lens over a stationary feed. The prototype was assembled with Styrofoam for anechoic chamber tests only, which did not allow demonstration of the azimuth scanning.

Herein, we show a similar mechanical steering concept in a fully functional prototype, both with elevation and scanning steering. But now the translation movement is done by the feed and not by the lens. In this way the in-plane dimensions of the antenna are kept fixed and compact during steering. The amplitude and phase corrected feed enables to lower the total antenna height. Total volume becomes 195×145×80 mm^3, weighing less than 500 g. This configuration potentially requires very low DC power to move both the 20 g feed and 200 g main lens, which is an attractive feature for a user terminal. With this prototype we show that the concept proposed in [2] can be implemented in a practical system without significant degradation of the antenna performance. The maximum measured gain is 27 dBi at 30 GHz, the scan loss is 3dB for an elevation scanning range of [18º, 53º], the cross polarization level is below -14 dB and the side love level is below -10 dB.

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II. Antenna Structure

A. Antenna components

The antenna is composed of two parts (see Fig. 1): i) the main lens, which is a planar offset Fresnel lens designed as in [2], is formed by an appropriate assembly of multi-layer printed phase-shifting cells arranged in a 2.5 mm lattice, with 3.35 mm total thickness; ii) the primary feed, which is composed of a circular-polarization patch (active) and a small lens that shifts downwards the phase center of the patch, allowing to decrease the overall antenna height (further details can be found in [2]). The antenna is designed to operate in the 30 GHz uplink Ka-band.

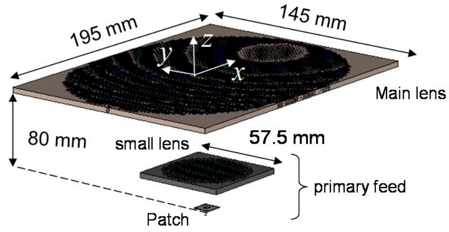

Fig. 1 - Antenna structure.

B. Antenna support system

The mechanical structure that supports the antenna provides two types of movements: i) Horizontal translation of the primary feed (patch and small lens) below the main lens and parallel to its symmetry axis. The travel length is up to plus/minus 30 mm with respect to the lens center. This is responsible for beam steering in the elevation plane; ii) 360º azimuth rotation of the platform that holds the feed and the main lens. This is used for azimuth scan. The supporting structure is 3D printed in ABS and it weighs less than 300 g. Fig. 2) shows the fabricated prototype used for the measurements.

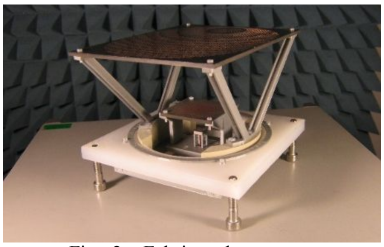

Fig. 2 – Fabricated prototype

III. MEASUREMENTS

Fig. 3 shows that the measured SWR of the prototyped patch is below 1.5 for all the uplink Ka-band as intended.

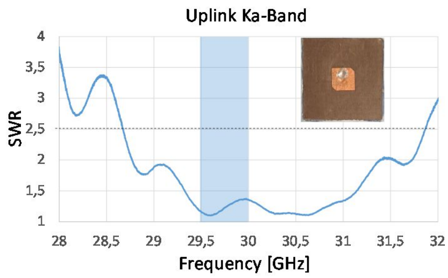

Fig. 3 – Measured SWR of the circular polarization patch .

We measured the radiation pattern of the developed antenna with the described support for different feed positions from -30 mm to 30 mm with 15 mm step. The co- (solid lines) and cross-polarization (dashed lines) components of the radiation patterns are plotted in Fig. 4. It shows a beam scanning in the [18º to 53º] interval that is enough for most cases of communications with equatorial satellites. When the feed is at the central position (x=0 mm, red curve) the beam points to 32º, It corresponds to the optimal offset Fresnel correction. As explained in [2], the level of aberrations increases with the feed displacement relative to the central position. The elevation scan loss is 3 dB for this lens. The SLL is below -10 dB for all beams.

We should stress that usually Fresnel lens systems tend to present a high level of reflections. Due to the careful design, the unit cells that compose the lens present very low level of reflections, worst case occurring for the most tilted beam (x= –30 mm) where the reflected beam level is 15 dB below the corresponding forward lobe. Moreover, the designed unit cells confer the lens a high level of polarization independence, justifying the low level of cross polarization, below -14 dB.

It is clear that the offset scanning approach can be used in these systems to improve the overall antenna performance. In Table 1 we summarize the main performance parameters. These values are very similar to the ones obtained with the ideal Styrofoam-supported prototype from [2], where only elevation steering was possible.

We also confirmed that the antenna performance is similar in the entire uplink Ka-band, [29.5, 30.0] GHz.

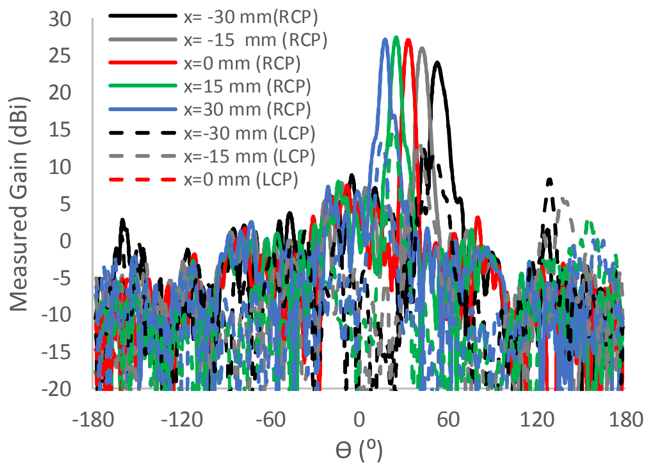

Fig. 4 – Experimental radiation patterns at 30 GHz.

Table 1 - Evaluation of the lens performance

FEED POSITION (mm)	GAIN (dBi)	SCAN LOSS (dB)	XPD (dB)	SLL (dB)	BEAM DIRECTION (º)
-30	24	3	-14	-12	53
-15	26	1	-15	-18	43
0	27	0	-14	-26	33
15	27	0	-14	-21	25
30	27	0	-17	-10	18

IV. CONCLUSIONS

In this work a prototype of a mechanical beam steering antenna for SOTM applications at Ka-band is fabricated and measured. The designed antenna has full azimuth coverage and elevation scanning capability produced by in-plane translation of the feed. The study proves that a very simple and light mechanical structure can be used to accommodate the proposed in-plane feed translation concept, with virtual focus for reduced antenna height, and wide scanning angle with little perturbation with respect to the ideal prototype from [2]. It further indicates that this antenna is potentially simple to fabricate, low-cost, thus attractive for mass applications.

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