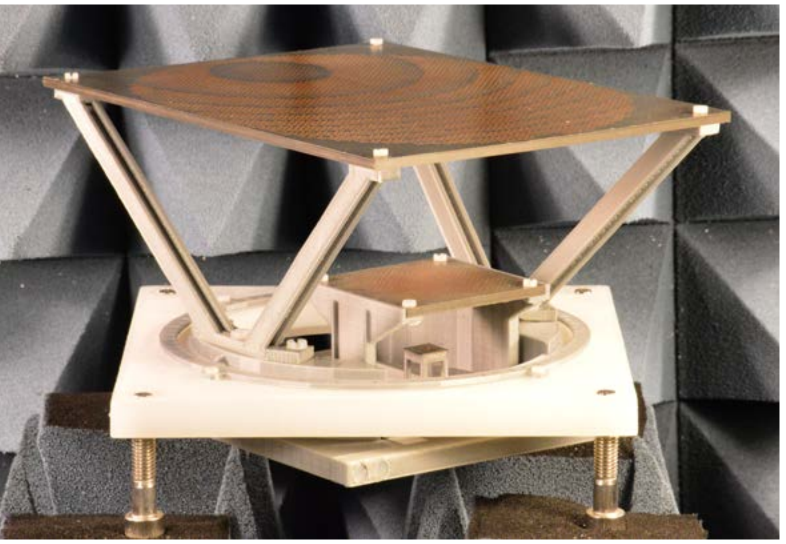
Millimeter Wave Antennas for Next-Generation Satellite Mass Services

Ka-band (20/30 HGz) satellites are expected to offer soon wireless broadband services for on-the-move users. Link budget imposes very high gain on the user terminal side, so automatic beam steering is required. Light and affordable antennas with high gain and steerable beam are needed. A new concept is proposed involving a thin planar metamaterial lens with in-plane feed translation, weighing less than 1 kg.



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Indicators	
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Journal Papers	4
Conference Papers	11
Concluded MSc Theses	2

Two Main Publications

J. S. Silva, E. B. Lima, J. R. Costa, C. A. Fernandes, J. M. Mosig, **Tx-Rx lens-based satellite-on-the-move Ka-band antenna**, IEEE Antennas and Wireless Propagation Letters, Vol. 14, pp. 1408 - 1411, March, 2015

E. B. Lima, S. A. Matos, J. R. Costa, C. A. Fernandes, N. Fonseca, **Circular Polarization Wide-angle Beam Steering at Ka-band by In-plane Translation of a Plate Lens Antenna**, IEEE Transactions on Antennas and Propagation, Vol. 63, No. 12, pp. 5443 - 5455, December, 2015

PROJECT WEBPAGE URL
https://www.it.pt/Projects/Index/1798

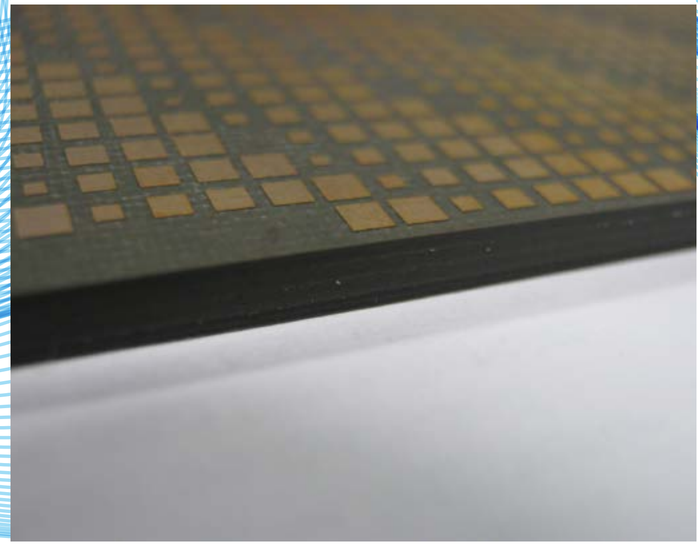

Fig. 1 Detail of the lens metamaterial cell pattern.

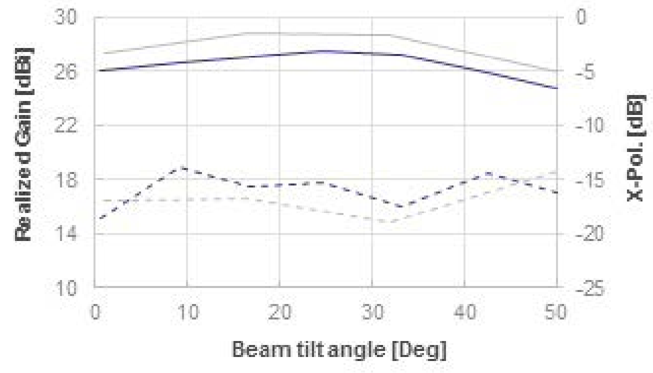

Fig. 2 Realized Gain and X-Pol vs beam tilt simulated (blue curve), measured (red curve) (solid line – RHCP, dashed line – X-Pol).

GENERAL MOTIVATION AND OBJECTIVES

The next generation of Ka-band satellites and high altitude platforms (HAPs) has the potential to boost the market of small ground terminals for mobile broadband access services. This anticipates the need for compact, low-profile and low-cost user terminals appropriate for mass market production. High gain antennas are required for the link budget, with beam agility to maintain the link while on-the-move. Mechanical beam steering solutions are attractive for the ground-segment of Satcom-On-The-Move (SOTM) terminals due to its potential lower cost compared to electronic steered antennas at millimeter waves. However, mechanical systems tend to have a considerable swept volume and weight, which limits its use mainly to large transport platforms. The goal of this project, funded by FCT-PTDC, is to explore new antenna concepts using metamaterials to counter the drawbacks of existing mechanical steering antennas without sacrificing significantly the electromagnetic performance.

CHALLENGE

The antenna solutions must be compatible with four essential attributes – low-profile, mechanical simplicity, energy efficiency and compatibility with low-cost mass production process – targeting not only commercial moving platforms (high-speed trains, buses or airplanes) but also personal vehicles (small boats or all-terrain vehicles). All this must be met while being competitive with the electromagnetic performance of long proven, but costly and heavier conventional technologies.

WORK DESCRIPTION AND ACHIEVEMENTS

The new concept involves a thin planar lens designed with an offset phase correction law and an especially designed primary feed composed by a circular polarization patch antenna with a small phase correction lens on top (see Figure). Elevation beam steering is obtained by in-plane translation of the feed system. Solidary rotation of the lens and feed provides full 360º azimuth beam steering. The patch plus small lens assembly are designed to lower the system F/D to about 0.55. Thus the developed two-lens configuration leads to a low profile, low weight antenna solution, requiring a very simple mechanical support system, adequate for ground terminal antennas and compatible with low-cost fabrication.

The planar lenses are formed by an assembly of sub-wavelength phase shifting cells, of the capacitive type (square patches). About 300º phase shifting range is obtained with the designed collection of cells, maintaining better than 0.4 dB insertion loss at the 30 GHz Ka band. The large lens aperture is oval to avoid spillover when the feed is in-plane translated away from the lens center position over the linear scan path.

A proof-of-concept prototype was pre-designed for operation at 30 GHz without too much effort on antenna performance optimization. The size of the larger (oval) lens aperture is of the order of 14.5 cm x 19.5 cm and the total antenna height (measured from the feeding patch to the top lens) is about 8.5 cm. Both the large and the smaller lenses were constructed using four bonded layers of Duroid 5880 with the pre-designed metal patterning. The maximum realized gain of the antenna is about 27.5 dBi and the beam can be scanned in the elevation plane up to 50º with a maximum scan loss of 2.8 dB. Owing to the system geometry, the elevation pattern is rigorously the same for any azimuth angle.

The larger lens weighs about 250 g while the supporting structure, built with 3D additive printing technology, weighs also about 250 g. Similar weight may be achieved with the industrial injection moulding technology. The interesting fact is that the moving part (lens plus the azimuth rotation stage and feed) weigh only 350 g. This requires a very low power motor to drive the azimuth rotation of the structure. On the other side, the feeding stage weighs less than 30 g, so an even lighter motor can drive the linear stage. This ensures that the mechanical part of the antenna structure is also very low-cost and very energy efficient.

So this is a promising antenna for SOTM applications at Ka band, requiring low operation volume, low power consumption while offering interesting electromagnetic performance.