Metasurface Sectoral Isoflux Beam Antenna for Space Application

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***Abstract*— In this work, we describe design and realization of a metasurface (MTS) antenna radiating a sectoral beam with isoflux envelope, suitable for Earth observation missions from LEO satellites. A Ka-band prototype, composed of a MTS antenna fed by a circular waveguide, has been realized and measured. Here we report the design steps and experimental results of the realized prototype.**

Keywords—Metasurface antenna; Leaky wave antennas; modulated surface impedance; space antennas; surface waves, isoflux.

I. INTRODUCTION

In the last years, planar antennas based on modulated surface impedance have emerged as a promising solution for space applications [1]. These antennas transform a surface wave (SW) into a leaky wave (LW) through the use of a modulated impedance surface implemented as a metasurface (MTS). At microwave frequencies, the MTS consists of a dense pattern of electrically small patches arranged in a Cartesian lattice and printed on a grounded slab. The major advantages of these antennas are simplicity of the feeding structure, low profile and low weight, reduced complexity and cost of manufacturing. Recent developments [2]-[3] have led to the availability of design procedures and electromagnetic modelling techniques allowing for an efficient and versatile control of the radiation pattern through the proper modulation of the surface impedance.

This paper summarizes the results obtained in the framework of the project *Low Complexity Data Downlink Antenna* (LCDA) financed by the European Space Agency (ESA). The activity has demonstrated the possibility of using modulated MTSs for LEO missions to obtain a minimum complexity, low-mass, low-envelop data down-link antenna in the Ka-band (26.3-27 GHz).

The realized prototype radiates a sectoral beam with isoflux envelope. Rotating the antenna around its symmetry axis allows the azimuthal scanning and provides the desired isoflux Earth coverage.

II. PROTOTYPE DESIGN

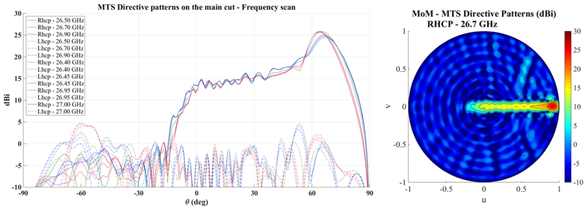
The functional parts of the prototype are mainly two: (*i*) the radiative panel based on a modulated MTS and (*ii*) the feeding system of the MTS.

A. Design of the Radiative Panel

The radiative panel is a MTS implementing anisotropic, modulated impedance boundary conditions (BCs) transforming a cylindrical SW into a LW with controlled amplitude, phase and polarization. The following steps summarize the design process.

- The aperture field has been initially determined generalizing the procedure in [4] and then refined through an optimization.
- Next, the impenetrable impedance surface has been designed assuming it as a lossless, continuous, tensorial reactance with capacitive nature. At this step, fields and currents on the impedance surface are described by an asymptotic form of the Floquet theorem, adiabatically extended to curvilinear, locally periodic BCs [2]. The synthesis process determines phase and amplitude of the modulation for each component of the tensorial impedance by matching the -1 FW with the objective aperture field [3].
- Finally, the synthesized continuous impedance surface is sampled on a regular Cartesian lattice, with cell size around one sixth of the free space wavelength, and implemented as a texture of metallic patches with elliptical shape. The geometrical parameters of the patches are chosen within a data base filled in with the results coming from a full wave analysis of each patch immersed in a periodic environment.

Full-wave numerical predictions of the field radiated by the continuous impedance surface obtained by the MoM solver described in [5] are reported in Fig. 1.



(a) (b)

Fig. 2 Numerical simulation of the realized prototype (a) cut along the spectral line u=0. (b) Directive pattern in the u-v spectral plane. Results have been obtained using the full-wave solver described in [5].

B. *Feeding Structure*

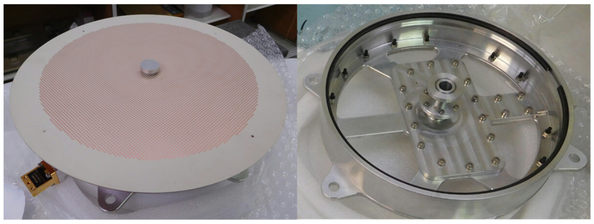
The input of the feeding structure of the LCDA antenna is a rectangular waveguide (RW), excited with a TE_{10} mode and converted into a TM_{01} mode of a circular waveguide (CW). The RW-CW transition structure is made highly symmetric so as to avoid the generation of the fundamental mode inside the CW. A rotary joint made of a $\lambda/4$ choke allows to mechanically separate the rotating part (i.e. the radiative panel) from the fixed part (i.e. the feeding structure), still maintaining the electric continuity. Atop the antenna, a matching hat ensures that most of the power in the CW is converted to SW power on the radiative panel.

III. ANTENNA REALIZATION AND MEASUREMENT

The realized prototype is shown in Fig. 3: Fig. 3a shows the radiative panel with the matching hat on top of it. The substrate employed (Rogers TMM10i) has relative permittivity 9.8 and thickness 0.508 mm. Fig. 3b shows the feeding system with the circular waveguide at its center. The feeding structure is realized in aluminum and it allows rotating the radiative panel. Unfortunately, during the assembling process, the radiative panel has been damaged, causing a slight curvature of the radiating structure and the breakage of the dielectric substrate. Measured directivity patterns along the main cut (spectral line u=0) of the damaged prototype are shown in Fig. 4. They exhibit slight differences with respect to numerically predicted results, probably mainly due to the damage. A new prototype is under manufacturing and measurements on it will be presented during the conference. Fig. 5 shows the reflection coefficient measured at the input port.

IV. CONCLUSIONS

We have reported the design and measurement of a prototype of MTS antenna radiating a sectoral beam with isoflux beam for LEO observation missions. The full-isoflux coverage of the Earth is obtained by mechanical rotation of the radiative panel. The antenna has been developed in the framework of the ESA project *Low Complexity Data-Downlink Antenna*. Measurements herein shown are relevant to a prototype that underwent a damage and slightly differ from the numerical prediction. A new prototype is currently under manufacturing and measurements on it will be presented during the conference.



(a) (b)

Fig. 3: Realized prototype. (a) Radiative panel mounted on the feeding structure (bottom-left corner: the input RW). (b) Rotating feeding structure (at the center: CW exciting the SW on the radiative panel).

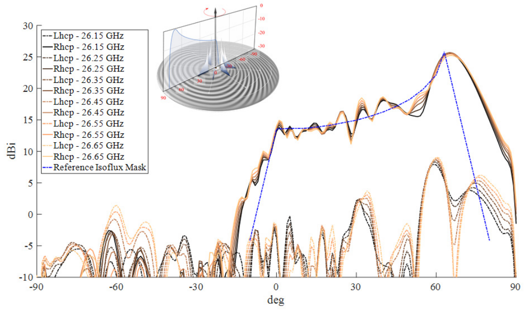


Fig. 4 Measured directivity patterns along the main cut within the band 26.15-26.65 GHz.

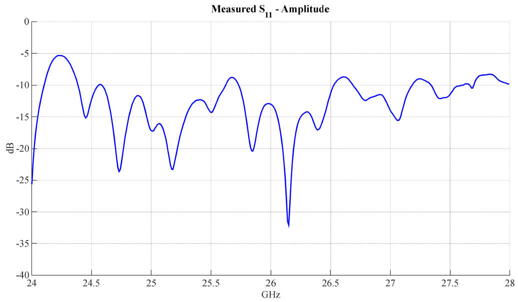


Fig. 5 S_{11} parameter measured at the input port of the feeding structure.

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