

Low Profile Wideband Scanning Antenna in Ka-band Based on Fully Metallic Metasurfaces

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Abstract – In this paper, a high gain antenna based on low profile metasurfaces is designed and numerically analyzed. The operation principle is the same of series fed Continuous Transverse Stub (CTS) structures, but in comparison to prior designs, radiation efficiency and compactness are improved by feeding the radiating aperture with a planar lens working in reflection. The lens can be realized using a pin-type metasurface, resulting in a fully metallic construction. The radiating aperture is realized by etching slots in the upper wall of a parallel plate waveguide loaded with corrugations; this solution provides an almost frequency- and scan-independent active impedance, resulting in wideband performance for all the pointing directions. Furthermore, because of the axial symmetry of the feeding structure, the antenna has the capability of generating multiple beams from the same aperture while maintaining excellent port decoupling.

I. INTRODUCTION

Satellite mobile communications have grown at an exponential rate in recent years as a result of the introduction of numerous new mega-constellations. In the ground segment, this calls for low-cost high-gain antennas with wide beam-scanning capabilities, as well as a low profile and low power consumption. From a technological standpoint, phased array antennas might be an option; nevertheless, they are currently too expensive and power-demanding for the consumer market. Traditional mechanically scanned reflectors, on the other hand, are too large and heavy for mobile platforms.

Recently, low profile solutions based on unconventional mechanical scanning mechanisms have been proposed [1]. In this solution, a radiating aperture consisting of a slotted parallel plate waveguide is excited by a corporate feeding network sitting on an underlying layer. Through a relative or common rotation of the two layers the beam can be scanned continuously in the upper hemisphere with no need for phase shifters.

A novel solution based on this concept is presented in this paper. The main novelty is relevant to the replacement of the corporate feeding network with a metasurface-based lens working in reflection, according to the principle presented in [2]. This solution allows for an extreme compactness of the overall antenna structure; furthermore, thanks to the axial symmetry of the lens, it provides multibeam capability.

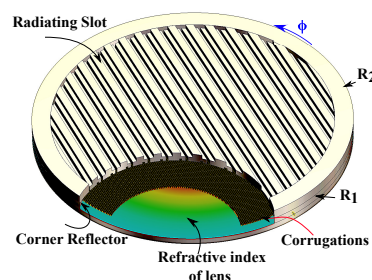


Fig. 1: 3D view of the complete design

II. ANTENNA DESCRIPTION

The complete structure consists of two parts: a Reflecting Luneburg Lens (RLL) realized in the bottom layer serves as a feeding structure, while a periodic array of slots is placed in the upper layer as a radiating structure. The two parts are coupled by a corner reflector.

A. Feeding Structure

The radiating part on the top is fed by a lens placed in the bottom layer, designed in circular shape and realized in a parallel plate waveguide (PPW). The lens is designed according to the operation principle introduced in [1]: the azimuthally symmetric modulation of the effective refractive index is designed to collimate in the upper layer, after reflection at the lens boundary, the rays launched by a point source located at the periphery (see Fig.2). A more practical and compact structure is obtained by using as primary feed a printed horn positioned at the internal quasi-focus point. The modulation of the refractive index profile can be obtained by loading one wall of the parallel plate waveguide with a spatially variable metasurface. This latter can be realized either by printing electrically small patches over a dielectric slab or using metallic pins. The latter solution has the advantage to lead to a fully metallic structure, thus, reducing losses.

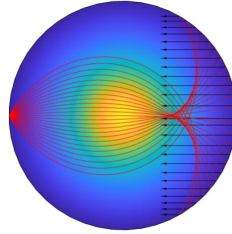


Fig. 2: Reflecting Luneburg Lens (RLL).

B. Radiating Structure

The radiating structure sitting in the upper layer is also realized in PPW, and can be developed by hollow waveguide technology. This PPW is loaded with corrugations to support a slow wave. It is excited with a planar wavefront by the underlying feeding structure, through a corner reflector. The relative rotational movement of the radiating and feeding structures, described by the angle ϕ , creates a variable phase gradient along the radiating slots, which is responsible for the beam scanning. Fig.3 shows the geometry of the unit cell of the radiating structure, which contains a reflection cancelling notch to allow for broadside radiation when the period is equal to the guided wavelength. By adjusting the parameters h_{notch} & u we can easily control the reflection coefficient of the unit-under all scanning conditions and in a broadband.

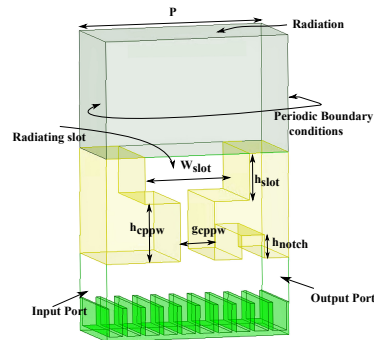


Fig. 3: Reflection cancelling unit cell with corrugated PPW. Unit-cell parameters are $h_{cpw} = 2.5mm$, $w_{slot} = 4.6mm$, $h_{slot} = 2mm$, $h_{notch} = 1mm$

III. RESULTS

The antenna structure has been designed with overall radius of 7λ and radiating aperture radius 6.1909λ at $29GHz$. At the design frequency, the reflection coefficient is lower than $-15dB$ and the coupling coefficient between facing ports is $-15dB$. Fig.4 presents the simulated radiation patterns under scanning conditions in the range between -60° to $+60^\circ$, corresponding to rotation angles from $\phi = -40^\circ$ to $\phi = +40^\circ$. within the scanning range the overall sidelobes are less than $17dB$. And the total efficiency is around 67% at broadside.

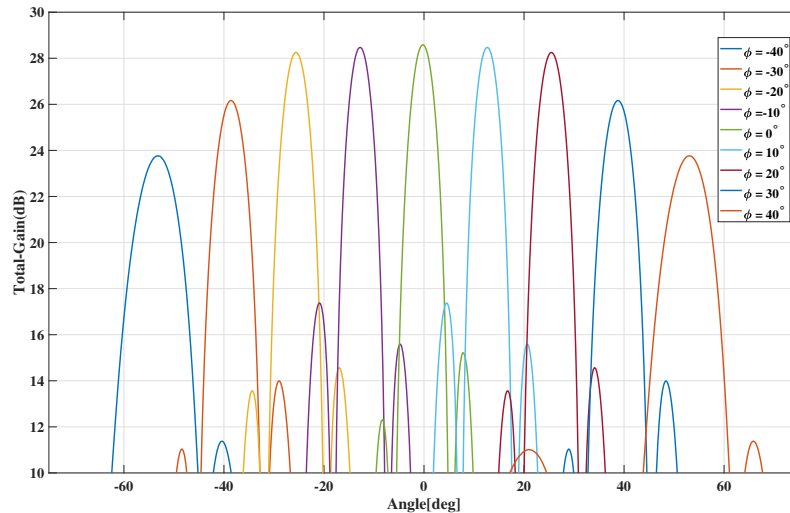


Fig. 4: Scanning performance in the E-plane at $f = 29GHz$. The step size of rotation angle is $\Delta\phi = 10^\circ$

IV. CONCLUSION

A compact, low profile high gain scanning antenna has been designed and numerically verified. Scanning is based on the series CTS principle, here combined with an innovative and effective solution for the beamforming network, based on a metasurface-based reflecting lens.

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