Low-cost transmit and receive reflectarray antenna for satellite communications in Ka-band

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Abstract-This contribution describes the design of a printed reflectarray to generate a focused beam in dual polarization at 19.7 GHz and also at 29.5 GHz, which are downlink and uplink frequencies for Satcom terminal antennas in Ka-band. The proposed reflectarray allows dual-frequency and dual-polarization operation, as well as simple and low-cost manufacturing. The simulated radiation patterns for a 20-cm reflectarray show a gain better than 30 dBi in both bands, with low levels for cross-polar radiation and side lobes.

Introduction: Ka-band has become a major alternative for satellite systems to satisfy the growing demand for capacity and provide broadband services. Conventional reflectors and phased arrays have been proposed for transmit and receive terminal antennas; however, the different frequencies for uplink (30 GHz) and downlink (20 GHz) lead to a more complex antenna design. Otherwise, reflectarrays can be designed for multi-frequency operation using a single layer [1] or stacked layers for each frequency [2]. A reflectarray working at 20 GHz and 30 GHz in orthogonal linear polarization was proposed in [3], so that only one linear polarization could be used at each frequency. In this paper, the authors present the design of a reflectarray VSAT antenna to simultaneously operate in dual polarization (linear or circular) at receive (19.7 GHz) and transmit (29.5 GHz) frequencies.

Reflectarray cell: The unit-cell used to provide the phasing on the reflectarray consists of two orthogonal sets of five parallel dipoles printed on a dielectric layer, and two additional sets of three parallel dipoles stacked above the first sets and printed on the top of a second dielectric sheet (see Fig.1a). The period, $P_X = P_Y = 6.5$ mm, is chosen as $0.66\cdot\lambda$ at the higher frequency (29.5 GHz) to avoid the appearance of grating lobes up to 30º incidence. This cell provides a smooth variation in phase response in a range greater than 360º at 19.7 GHz and 29.5 GHz. An independent phase control can be achieved based on the dipole lengths: upper dipoles will not disturb the phase response at 19.7 GHz, as they are shorter than the ones in bottom layer, while lower dipoles will behave as a ground plane at 29.5 GHz for higher layer elements. Thus, the dipole lengths can be first adjusted on the bottom layer to produce the required phase-shift at 19.7 GHz, and then, those on the top layer to provide the required phase at 29.5 GHz.

Antenna design: A 20-cm sided reflectarray, consisting of 900 elements arranged in a 30x30 grid, has been designed to generate a focused beam in the direction $\theta_b = 13°$, $\varphi_b = 0°$ for the two orthogonal polarizations (with the electric field in the direction of the dipoles) at 19.7 and 29.5 GHz. Since the antenna is designed to provide the same radiation pattern for the two orthogonal components of the incident field, it will operate in dual Circular Polarization (CP) when it is illuminated by a dual-CP polarized feed. The phase center of the feed is placed at coordinates (-40, 0, 195) mm relative to the reflectarray center, and the radiated field is modeled using a cos-q distribution, with q=10.5 for 20 GHz band and q=10.7 for 30 GHz band. A home-made software analysis routine, based on the Method of Moments in the Spectral Domain (MoM-SD) and the local periodicity approach, has been employed to optimize the dipole lengths in order to provide the phase-shift distributions shown in Figs. 1b and 1c for both polarizations at 19.7 GHz and 29.5 GHz, considering the real angle of incidence on each reflectarray element. The dimensions of all dipoles are optimized element-by-element to simultaneously match the phases at the central and extreme frequencies in lower (19.2-20.2 GHz) and higher (29-30 GHz) bands, following a procedure similar to that shown in [4].

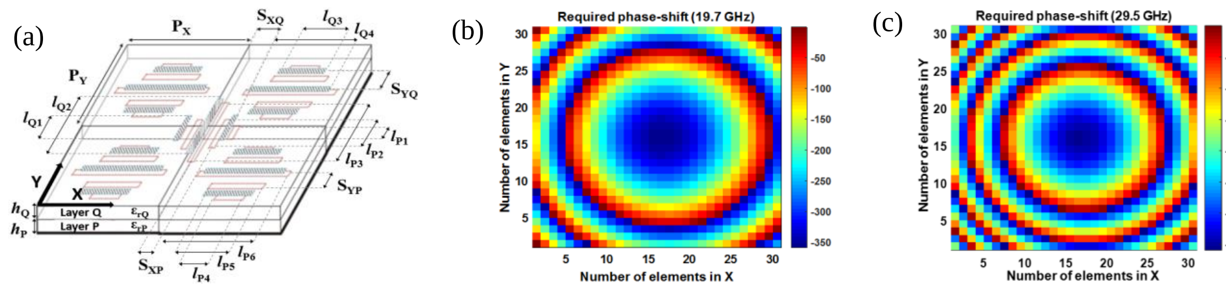

Figure 1. (a) View of reflectarray periodic structure. (b) Required phase-shift at 19.7 GHz and (c) at 29.5 GHz.

Results and conclusions: The simulated radiation patterns in gain (see Fig. 2), have been obtained from the tangential reflected field at each reflectarray cell, using the mentioned MoM-SD software. A gain of 31.4 dBi and 34.2 dBi is reached at 19.7 GHz and 29.5 GHz, respectively, with cross-polar radiation around -26.5 dB within a -3 dB main beam and side-lobe level close to -22 dB. An 8% and 5% bandwidth has been achieved in each band with a gain variation < 1 dB. The antenna efficiency can be estimated as 67% in lower band and 57% in higher band, considering illumination, spillover and dielectric losses. These results show the potential of reflectarrays for dual-frequency and dual-polarization operation as an alternative for Ka-band terminal antennas.

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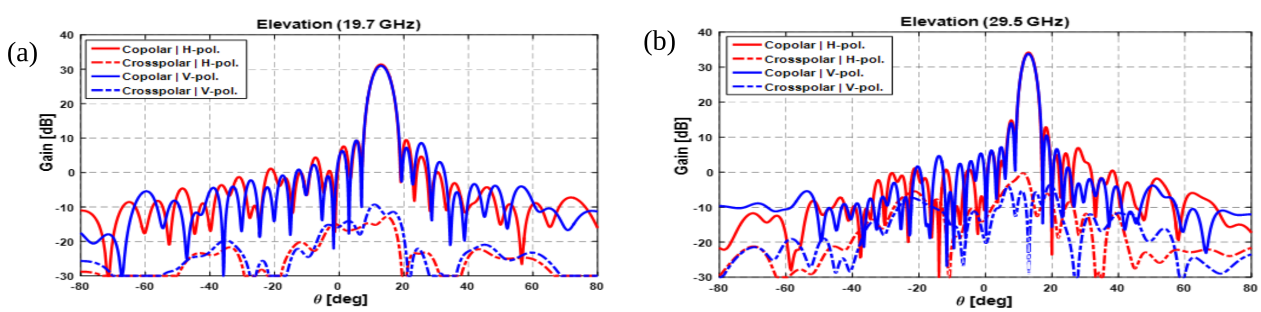

Figure 2. Simulated radiation patterns in gain (dBi): (a) XZ-plane at 19.7 GHz, (b) XZ-plane at 29.5 GHz.

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