A High-Throughput Deployable Antenna based on Not-Aligned Reflectarray Panels

Borja Imaz-Lueje(1), Daniel Martinez-de-Rioja(2), Marcos R. Pino(3), Manuel Arrebola(3)

(1) Department of Signal Theory and Communications, Universidad Rey Juan Carlos, Spain (borja.imaz@urjc.es)

(2) Information Processing and Telecommunications Center, Universidad Politécnica de Madrid, Spain (jd.martinezderioja@upm.es)

(3) Department of Electrical Engineering, Universidad de Oviedo, Spain, ({mpino, arrebola}@uniovi.es)

***Abstract*—This contribution describes a deployable large multi-faceted reflectarray to be embarked in different aerospace vehicles. The structure comprises several low-profile panels that are assembled to follow an equivalent parabolic reflector. An example of this antenna concept is designed to operate in Ka-band and dual-linear polarization. It provides high-gain, low-losses, and a bandwidth significantly higher than the one achieved with a conventional deployable reflectarray. Therefore, the proposed antenna exhibits high-throughput performance with integrability with the vehicle platform. Such features are of particular interest for space missions and some terrestrial communications.**

I. Introduction

Novel applications demand antennas onboard aerospace vehicles with high-gain and broadband features to provide large throughput communications. Deployable reflectarrays have been proposed to provide large apertures antennas with high-gain performance and integrability with the vehicle. This low-cost and energy efficient antenna solution has been of particular interest in several space missions [1], but also in UAVs platforms [2]. Nevertheless, large aperture reflectarrays exhibit typically an inherent narrow bandwidth, mainly due to the differential spatial phase delay. Broadband techniques such as multi-faceted structures [3] mitigates such effect, improving the bandwidth of the antenna without reducing the efficiency or its integrability with the vehicle.

This paper presents a large aperture multi-faceted reflectarray to be embarked in different aerospace vehicles. The structure comprises several panels that can be folded and deployed onboard, for instance, satellites for space missions (see Fig. 1(a)) or UAVs for 5G/6G millimeter-wave communications (see Fig. 1(b)) to improve the performance of reflecting intelligent surfaces (RIS) in smart EM environment [4]. The panels are based on a low-loss unit-cell and are arranged edge-to-edge, approximating the equivalent reflector with a 2D discretization. An example of such structure is designed and evaluated using a Method of Moments in Spectral Domain (MoM-SD) [5] and the multi-faceted analysis technique reported in [3].

II. Antenna Definition

The scenario to be considered in this study is depicted in Fig. 1(c). The multi-faceted structure (MFRA) consists of an electrically large aperture that operates at 30 GHz in dual-linear polarization (X- and Y-polarization). The reflectarray antenna must provide a high-gain pencil beam pattern per polarization.

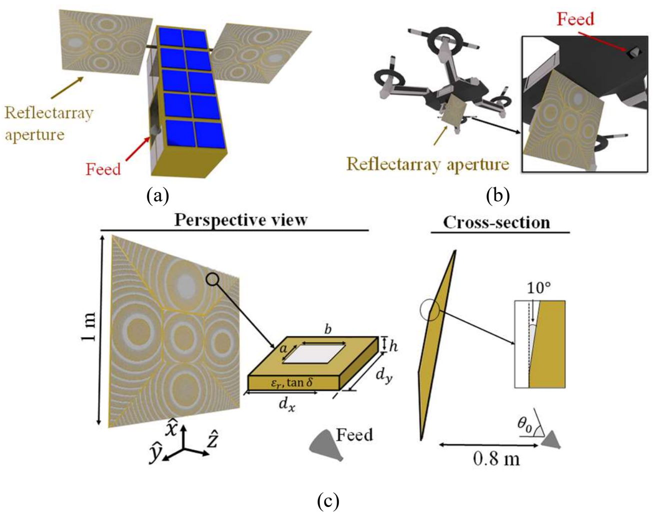

Figure 1. Examples of using the proposed reflectarray structure: (a) onboard satellite or (b) embarked in a UAV for 5G/6G communications; (c) Detail of the antenna optics and sketch of the phase-shifter.

A. Multi-faceted structure

Fig. 1(c) shows the optics of the proposed multi-faceted structure. It consists of 5 panels: one rectangular and 4 trapezoids. The central and side panels have roughly 5600 and 11000 elements respectively, distributed in a rectangular lattice. The panels are assembled following a parabolic profile, conforming a total aperture of 1 m.

The antenna optics consists of a single offset configuration. The primary feed is a horn antenna of 10 dBi, considered in the analysis as a $\cos^q \theta$ function. In each main plane of the feed, the q factor is (7.7,7.8) at 30 GHz and varies linearly in-band. The feed is located at 0.8 m from the reflector, and the subtended angle (θ_0 in Fig. 1(b)) is 58º. The entire structure has an f/D ratio of about 0.8.

B. Design of the reflectarray panels

The phase required in each reflectarray panel is calculated using the expression stated in [3] to generate a directive beam in the broadside direction $(\theta_b, \varphi_b) = (0.0,0.0)°$, considering the coordinate system of Fig. 1(b).

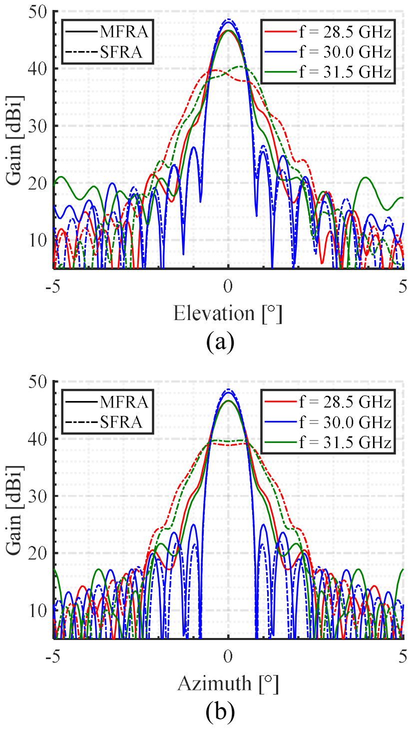

Figure 2. Radiation pattern in gain [dBi] of the multi-faceted reflectarray (solid lines) and its equivalent single facet reflectarray (dotted lines): (a) Elevation; (b) Azimuth. Polarization X.

The phase-shifter shown in Fig. 1(c) is used to provide the phase distributions calculated. It consists of a variable size rectangular patch, printed on a single layer of substrate, and backed by a ground plane. The substrate is diClad 5880 ($\varepsilon_r = 2.3; \tan\delta = 0.005$) with thickness $h = 0.762$ mm. The periodicity in both axes is $d_x = d_y = 4.3$ mm ($0.4\lambda_0$ at design frequency). The unit-cell evaluated using [5], exhibit angular stability and low losses, at the expense of a reduced phase range, limited to 280º.

The layouts of each panel have been calculated using an element-by-element process, in which the patch dimensions (a, b in Fig. 1(c)) are adjusted properly to provide the required phase distribution. Fig. 1(c) shows the layout of each panel. The variation of the patch sizes is smoother since the optics of the multi-faceted approach compensates partially the phase required in each panel, as devised in [3].

III. Antenna Performance

Fig. 2 depicts the radiation pattern of the MFRA compared with an equivalent single facet reflectarray (SFRA) evaluated in-band. Both antennas exhibit a directive beam at 30 GHz with a half power beamwidth (HPBW) of 0.6º x 0.6º, a side lobe level (SLL) of about -20 dB and a gain of roughly 48 dBi. At off-center frequencies, the proposed MFRA maintains these figures of merit, but the SFRA experience a significant defocusing of the main beam, which leads to a gain loss. Similar behavior can be found for polarization Y.

Fig. 3 shows the gain values of both antennas assessed in a wider range of frequencies. The MFRA exhibit high gain values

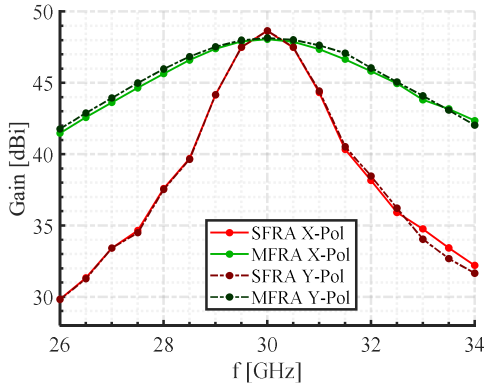

Figure 3. Gain over frequency for the proposed structure (MFRA) and its equivalent single facet reflectarray (SFRA).

along all the band under study, while the SFRA feature an evident loss of gain. The MFRA achieves a relative 1-dB gain bandwidth of 10%, which is 6 times higher than the bandwidth achieved with the SFRA.

IV. Conclusions

This contribution presents a deployable multi-faceted structure that can be integrated in aerospace vehicles involved in different wireless communications. The structure consists of panels with different shapes, arranged following an equivalent parabolic reflector. An example of this antenna concept has been designed and assessed to operate in dual linear-polarization in Ka-band. The proposed structure exhibits high-gain, low-loss and good in-band performance, significantly better than its equivalent single facet aperture. Other configurations or operational features of the proposed structure will be presented in the conference.

Acknowledgment

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