Study of Different Dual-Reflectarray Antenna Configurations for Beam-Scanning Applications

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I. INTRODUCTION

Dual-reflectarray configurations exhibits some advantages from both mechanical and electrical points of view with respect to reflector antennas. Dual-reflectarray antennas present a reduced volume and the capability of being easily folded. Furthermore, these antenna configurations provide phase control on both reflectarray surfaces [1], which can be used to improve the antenna performance for multiple beams, beam scanning or shaped beams. An electronic controllable reflectarray can be used as subreflector to drastically reduce the number of elements to be controlled for applications requiring steering or reconfiguration [2] of the beam such as Synthetic Aperture Radar applications. These antenna configurations present a high applicability to SAR systems in which scanning with almost no degradation of the beam is of high importance to avoid performance degradation over the swath [3].

This paper presents the recent work on dual-reflector antennas involving two flat reflectarrays for beam scanning applications. Three antenna configurations using either passive or reconfigurable reflectarrays as sub and main reflector in different frequency bands are shown and discussed. The performance and capabilities of these antennas are shown by describing some practical design cases in Ku-band and F-band.

II. Antenna configurations

The three antenna configurations, which will be described in more detail in the final paper, are defined as follows: In the first architecture, a dual offset reflector is implemented with two flat passive reflectarrays at 94 GHz. In this antenna, the main reflectarray focus the beam emulating a parabolic reflector. The beam is focused in the boresight direction of the equivalent parabolic reflector when a flat metal sub reflector is used. Fig. 1(a) represents the geometry of this antenna. The main reflector diameter is 120-mm and the sub reflector diameter is 28-mm diameter. When the metal sub reflector is replaced by a reconfigurable reflectarray that introduces a progressive phase shift, the beam can be scanned in a range from -5º to +5º in either elevation or azimuth. To demonstrate the validity of the concept the passive reflectarray reported in [4] has been used to deflect the beam 5° in azimuth. The antenna is analysed by the technique proposed in [5].

In the second antenna configuration, the main reflectarray is passive and the beam scanning is achieved by introducing a phase-control in the elements of the sub reflectarray. The antenna provides beam scanning in a range of 13 degrees on the elevation plane using elliptical reflectarrays of axes (1175 mm, 962mm) for the main and (250 mm, 225 mm) for the sub reflectarray. The main reflectarray is designed to emulate the behaviour of a parabolic reflector, producing a focused beam in θ_0 direction when the phase distribution on the sub reflectarray is uniform, while the sub reflectarray is used to introduce the appropriate progressive phase in order to scan the beam. This antenna has been designed at 12 GHz [2] and its performance is analyzed in the frequency band from 10.7GHz to 14 GHz.

A third alternative is also studied, in which the beam scanning is produced using reconfigurable elements on the main reflectarray, while a passive sub reflectarray is designed to provide a large focal distance within a compact configuration. In this case, the antenna is defined to provide a directive beam in receive (10.70-12.75 GHz) and transmit (14.0-14.5GHz) frequency bands with electronic scanning capabilities within a certain angular range. The proposed main reflector has a pentagonal shape with its larger dimension on the X-axis. The main dimensions are: 3B/2=750 mm, h=3000 mm and df=2518 mm, see Fig. 1(c). The dimensions of the sub reflectarray are 500 mm × 600mm. The antenna can be folded and packed in a suitcase with dimensions 700 mm × 700 mm × 400 mm. [6] .

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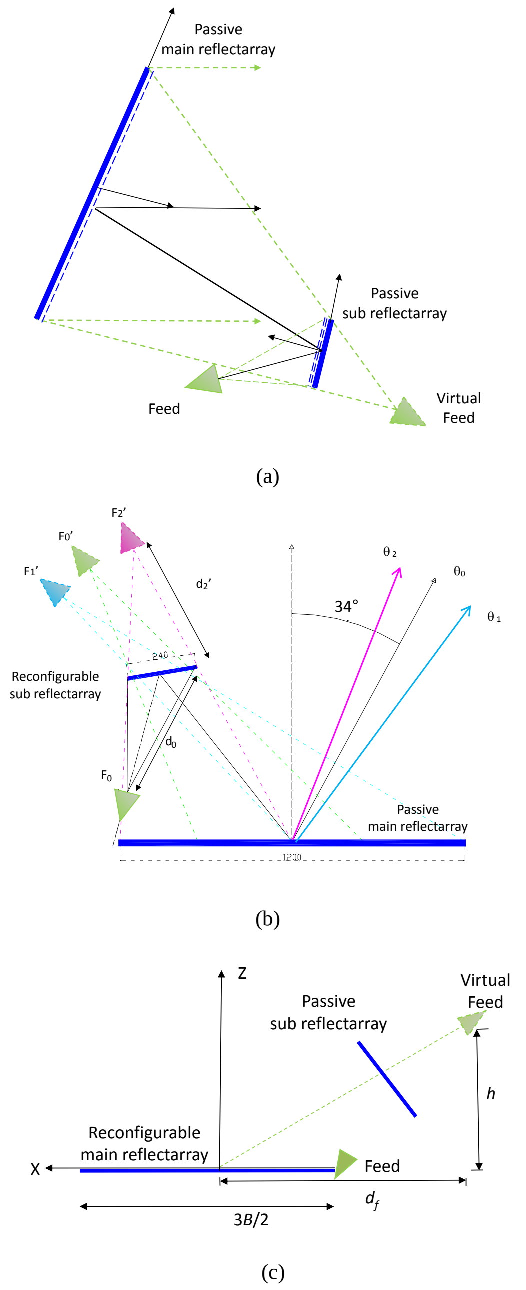

Figure 1. Lateral view of dual-reflectarray antenna for the first (a), second (b) and third (c) configurations.

III. ANALYSIS OF THE ANTENNAS

The three antenna configurations presented here have been analyzed and the results will be shown more in detailed in the final version of the paper. The results obtained for the first antenna configuration show that the near field radiated by the horn must be included in the analysis to provide accurate results.

The second dual-reflectarray antenna designed to steer the beam in a range of 13 degrees (-8 to 5 degrees), present acceptable preliminary simulated results for beam scanning capabilities in a frequency band larger than a 10 %. The radiation patterns present a good behaviour in azimuth and a slight distortion in elevation. A beam squint of approximate 1 degree has been observed from 10 to 14 GHz, which must be compensated in the design. In this case, reflectarray elements on the subreflector are implemented as switched delay lines aperture-coupled to square patches. Ideal switches are considered in this study but in a practical case, they will be implemented by MEMS devices. Fig. 2. shows the elevation cut of the radiation pattern for the two deflected beams.

The preliminary results of the third antenna geometry present a satisfactory performance in the prescribe frequency bands for transmit and receive; only small errors in phase have been evaluated at different frequencies [7].

The results obtained for the 3 antenna configurations show the feasibility of dual-reflectarray antennas to improve the antenna performance for beam-scanning applications, by using controllable phase-shifters in only one reflectarray and by properly adjusting the phase on the other passive reflectarray.

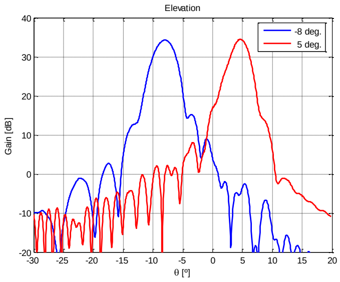

Figure 2. Radiation pattern for the second antenna configuration when the beam is deflected -5° and +8° in elevation.

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