Beam Reconfiguration Using Imaging Reflector Antennas

Sudhakar Rao, IEEE Life Fellow
Northrop Grumman Aerospace Systems
Redondo Beach, CA 90278, USA
skraoks@yahoo.com

Philip Venezia
Custom Microwave Incorporated
Longmont, CO 80501, USA
venezia@custommicrowave.com

***Abstract*—Beam reconfiguration of antenna payloads is becoming an essential requirement for future satellite systems used for commercial and military communications. This paper presents an imaging reflector antenna system that achieves beam reconfiguration using a cost-effective method.**

Keywords—Reconfigurable Antennas, Imaging Antennas, multiple beam antennas

I. Introduction

On-orbit operational flexibility requirements for future satellite antennas involve changes in coverage, beam scanning and interference mitigation . Types of antennas that could provide the desired on-orbit flexibility include phased array antennas (PAA), confocal reflector antennas (CRA), focal-plane reflector antennas (FPRA) and imaging reflector antennas (IRA). PAA becomes impractical for high gain applications since the number of elements required will be in the order of several tens of thousands [1, 2]. CRA is similar to PAA, but employs a parabolic sub-reflector and a parabolic main reflector with a common focal-point and the sub-reflector is fed with a phased array [3]. This system is not practical, although several theoretical studies were conducted and prototypes being built, and there are no satellite systems in space that employ CRAs. FPRA, either single or dual, has the feed array located in the focal-plane of the reflector. FPRA requires electrically small feeds (typically around one wavelength size) in order to get good adjacent beam overlap. Because of small feed size, the reflector (or sub-reflector in dual-reflector system) is not optimally illuminated and hence the antenna efficiency is very low (about 50%) [2]. Also, the beams do not combine well if a large area beam needs to be formed. Antenna systems that are suitable for these applications are IRAs, using either single or dual reflector antennas. This paper presents preliminary results of an IRA that can produce multiple element beams and larger coverage beam simultaneously. Multiple quiescent beams are used to create an adapted beam that can null a number of interferers or provide higher gain spot beams. The antenna beams are scanned together maintaining the adjacent beam overlap over global coverage regions using a hybrid scanning method.

II. Imaging Reflector Antenna

An imaging reflector antenna geometry is shown in Fig. 1, where the feed array is displaced from the focal plane in order to broaden the element beam and thereby improving the adjacent beam overlap. It allows use of large number of element beams to form high gain multiple beams (HGMBs) with improved gain. The HGMBs can be electronically scanned over a small theater coverage for precise pointing and coarse scanning using main reflector-only gimbaling with fixed feed array to achieve beam scanning over larger coverage region, such as global coverage. The antenna geometrical parameters are D = 129λ, F/D = 1.2, and H = 51.65λ, where λ is the wavelength at mid-band of low frequency. The feed array is defocused by h = 5.17λ in order to create imaging optics in the far-field. A 37-element feed array arranged in a hexagonal grid is used with inter-element spacing of about 1.2λ at the lowest frequency (Band 1). Measured patterns of the dual-band feed is shown in Fig. 2 (feed assembly shown as an inset in Fig 2). The center frequencies of the two bands are separated by a factor of 1.46.

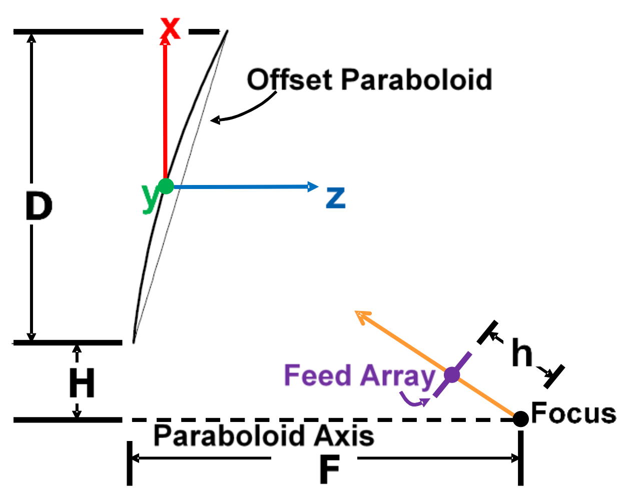

Figure 1: Geometry of an IRA

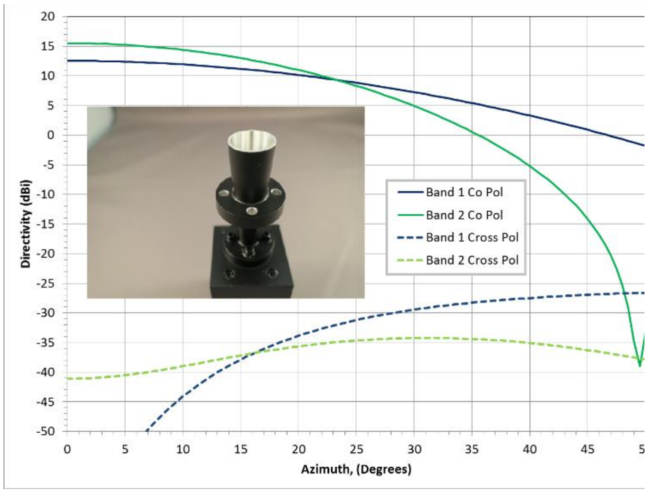

Figure 2: Radiation patterns of dual-band feed

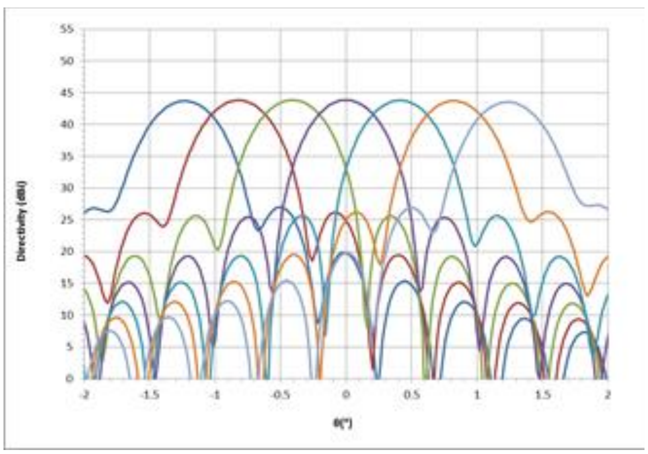

Figure 3: Computed element beam patterns of the IRA in azimuth plane. Each beam is generated with single feed.

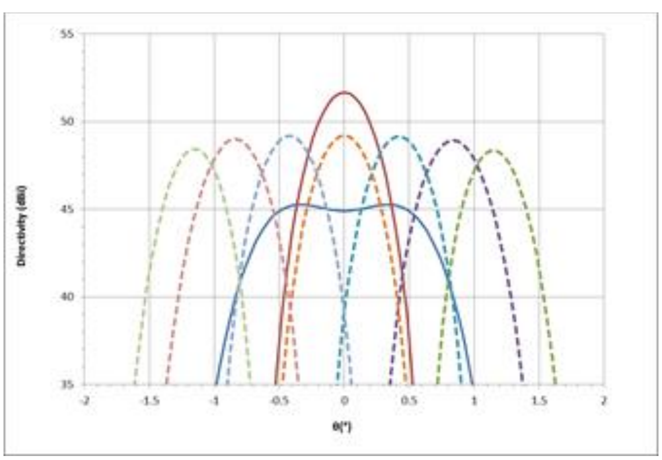

Fig 4: **High gain multiple beams (HGMB) are used to synthesize spot beam as well as coverage beam with higher gain values compared to conventional designs**

Fig. 3 shows computed patterns of 7 beams along the azimuth plane where each beam is generated using a single horn at Band 1. The efficiency of this antenna is only about 14% due to significant spill-over losses. By combining element beam patterns using an array of elements and then combing HGMBs (as shown in Fig 4) using a digital BFN, a very efficient spot beam with 82% efficiency and a very efficient shaped coverage beam with a gain-area product (GAP) of about 24,800 are achieved. Similar performance can be achieved at Band 2 (not shown here due to paper size constraints). Hybrid scanning methodology is described in Fig. 5.

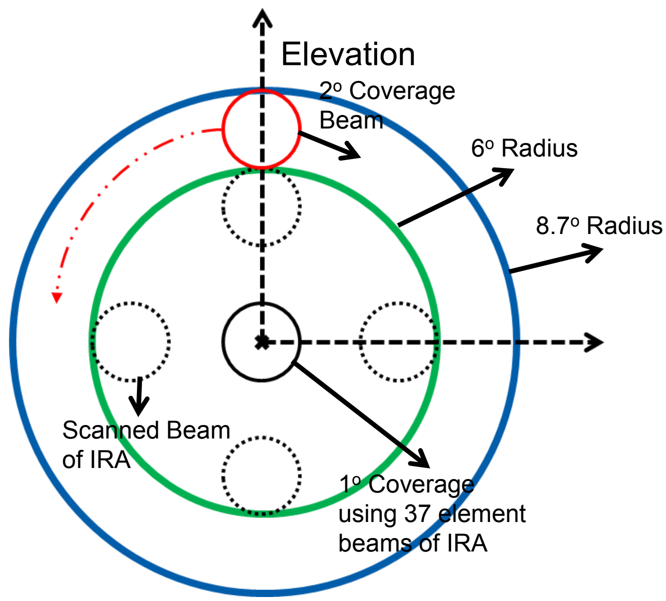

Fig 5: Illustration of hybrid scanning method

The beam reconfiguration achieved using the proposed method employs two levels of BFNs and gives more than 2.2 dB improvement compared to conventional methods. Proposed hybrid scanning reduces the number of elements in the image plane of the IRA and hence is a low-cost solution. This method is applicable for dual-band and multi-band operation also by designing feed assembly properly and optimizing the IRA geometry.

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