PHASED ARRAY GNSS ANTENNA FOR THE *FORMOSAT-7/COSMIC-2* RADIO OCCULTATION MISSION

Dmitry Turbiner, Larry E. Young, Tom K. Meehan
California Institute of Technology, Jet Propulsion Lab

ABSTRACT

Future GNSS remote sensing instruments such as the TriG receiver require more capable antennas than those flown on missions such as COSMIC. To maximize the number of ionospheric and atmospheric profiles, the TriG receiver will be capable of tracking legacy and new GPS signals such as L5, L2C and L1C; GLONASS CDMA and Galileo E1 and E5a. There has been an in-house effort at JPL to develop a set of antennas that would provide excellent Radio Occultations performance as well as navigation and ionospheric profiling. This effort is on-going but near completion for the manufacture and delivery of a set of flight antennas for the FORMOSAT-7/COSMIC-2 mission.

We will present aspects of the design and performance figures of an electronically steerable 12-element phased array to accompany the TriG instrument on COSMIC-2, the next RO mission. We will discuss specific features that help ensure the maximum scientific return. In particular, we designed custom helical elements and a low-loss broadband combiner networks. Also, each individual element is electrically phased in a way that synthesizes a final directivity pattern whose peak gains are distributed along the limb of the Earth.

According to HFSS simulations and measurements on built prototypes, we anticipate a realized peak gain of 18dBic and 16dBic at GPS L1 and L2/L5 respectively. This gain drops by 6dB at 55 degree azimuth. This antenna does not exceed a 60x40x10cm volume.

INTRODUCTION

An Antenna Array for Radio Occultations

For the upcoming COSMIC-2 mission, in order to obtain the best possible Radio Occultation measurements we needed to develop an antenna that produces high circular polarized gain, over the entire range of GNSS frequencies, along the earth's limb as viewed from low earth orbit. The antenna volume is limited to 60x40x10cm. Dozens of flight units at low-moderate cost needed.

Primarily, we would like to have as much Gain as possible over our wide Field of View.

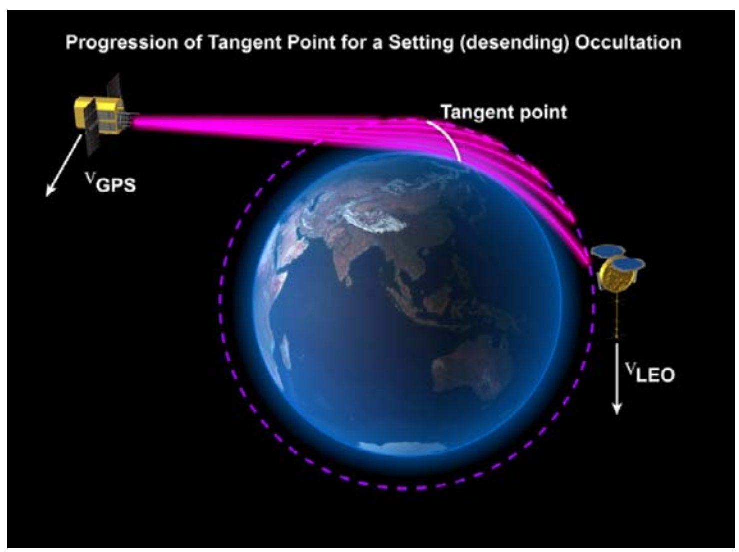

Fig 1. *A Radio Occultation experiment. The spacecraft on the left is a GPS satellite, the one on the right is a COSMIC-1 RO satellite in LEO orbit.*

Figure of Merit: *Aperture Efficiency*

Let's define the following quantities:

- ***Effective Aperture*** = Area over which the antenna extracts power from the incident wave.
  - ➢ $A_e = \frac{\Lambda^2}{4*\pi} * Gain$
- ***Physical Aperture*** = Cross-section area perpendicular to direction of incident wave
  - ➢ $A_p = 60 * 40 * cos(\theta_{incident})$
- ***Aperture Efficiency*** = A_e/A_p

(from Kraus, *Antennas)*

The figure of merit we have chosen for this problem is the Aperture Efficiency of our final antenna. In other words, to quantify the performance of our design, we compare the *Effective Collecting Area* of our antenna to the *Theoretical Collecting Area* of a 100% efficient aperture of the physical size of our antenna, ie: 60 x 40 x COS(-25deg) = **2175 cm^2**

Implementation

In order to maximize the Effective Collecting Area of our array, we focused on coming up with:

1. *The Optimum Array Geometry*
2. *High Efficiency Antenna elements*
3. *Lowest-loss combiner network*

We selected the individual elements gain and the array geometry in a way that effectively "fills-up" our available 60 x 40 cm^2 physical aperture.

We electrically combine our elements into sub arrays that have intrinsic gain patterns that match our required field of regard: the gain peaks are distributed along the limb of the Earth for each frequency used. Individual beams are then digitally formed inside the GNSS receiver.

We developed custom antenna elements that are broadband, high-efficiency, have low mutual coupling, and have a specific input impedance.

We also developed a very-low-loss broadband feed network which avoids the use of impedance transforming networks or transmission line transitions, and employs a minimum amount of dielectric material.

Results

Theor. Ant (100% efficiency)	Effective aperture: 40 x 60 x COS(-25deg) =	$2175cm^2$
Frequency	AZ = 0 deg	AZ = 55 deg
L1 (1575 MHz)	18.8 dBic	16.4 dBic
L2 (1227 MHz)	16.6 dBic	14.2 dBic
L5 (1176 MHz)	16.2 dBic	13.8 dBic

SIMULATED (HFSS)	Effective aperture:	34 x 54 = $1810cm^2$
Frequency	*AZ = 0 deg*	*AZ = 55 deg*
L1 (1575 MHz)	18.0 dBic	10.5 dBic
L2 (1227 MHz)	15.7 dBic	10.7 dBic

BUILT & MEASURED	Effective aperture:	30 x 51 = $1541cm^2$
Frequency	AZ = 0 deg	AZ = 55 deg
L1 (1575 MHz)	17.3 dBic	

Summary

The antenna described in this paper has been selected to be flown on the FORMOSAT-7/COSMIC-2 constellation of 12 LEO satellites *(initial 6 spacecraft launch in early 2016).*

It offers significant improvements over antennas from previous Radio Occultation missions (such as FORMOSAT-3/COSMIC and CHAMP):

- Approx 10dB more gain
- Multiple simultaneous digitally-steerable beams
- Supports signals from all GNSS Constellations

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REFERENCES

Aspects of this design are part of Caltech provisional patent 61/664,312

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