Radio Beacon Monitoring for Ionospheric Scintillation Specification and Total Electron Content from the FORMOSAT-7/COSMIC-2 Science Mission

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19-23 August 2019 – International Beacon Satellite Symposium, Olsztyn, Poland

COSMIC-2 RF Beacon

Outline

• FormoSat-7 / COSMIC-2 Mission
• RF Beacon System
  ▪ Space/Ground components
• Early sensor Checkout & Commissioning
• Beacon system Cal/Val

FormoSat 7: Program name used by the Taiwan National Space Organization (NSPO)
COSMIC-2: Constellation Observing System for Meteorology, Ionosphere, and Climate
FORMOSAT-7 / COSMIC-2 Mission

- Joint mission between US and Taiwan
- Successful launch 25 June 2019
- 6 Satellites, 24° inclination
- Initial altitude of ~720 km, will come down to ~550 km one at a time

Goal: Provide a revolutionary increase in the number of atmospheric and ionospheric observations greatly benefiting research & operational communities

- Space Situational Awareness Environmental Monitoring (SSAEM) Sensor Package
FORMOSAT-7 / COSMIC-2 Mission

Space Situational Awareness Environmental Monitoring (SSAEM) Sensor Package

**Ion Velocity Meter (IVM)**
Gridded electrostatic analyzers for *in-situ* ion density, temperature, & 3D drifts (E-Fields)

**Tri GNSS RO Sensor (TGRS)**
Fore & Aft looking RO sensors capable of tracking GPS & GLONASS at high-rates for space-based ionospheric scintillation measurements

**RF Beacon**
3-Frequency Beacon (plus Channel Probe) for ground-based measurement of scintillation and total electron content (TEC)

**Scintillation Goal:** To develop a fully coupled system to take advantage of Space/Ground-based data from COSMIC-2 to improve the global characterization of scintillation.
FORMOSAT-7 / COSMIC-2 TGRS

- Multi-GNSS capabilities
- Fore & Aft antennas
- Scintillation & TEC
- >1000 occultations/day/satellite

TGRS pictures courtesy JPL

FORMOSAT-7 / COSMIC-2 RF Beacon

- **Three Frequency Beacon:**
  - UHF (400 MHz), LBAND (965 MHz), SBAND (2200 MHz)
- Nadir pointing RF Beacon Antenna
- System designed with consideration for RFI impact to other spacecraft sensors
- 100% duty cycle
- Primary products from beacon signals:
  - $S_4$
  - $\sigma_\phi$
  - TEC
FORMOSAT-7 / COSMIC-2 RF Beacon

• Ground Segment:
  ▪ Designed to meet requirements at 20° elevation:
    – \( S_4 \): range 0 to 1.5, uncertainty to 0.1
    – \( \sigma_\phi \): range 0 to 20 radians, uncertainty to 0.1 radians
  • This translates to an SNR requirement of 23 dB
  • To meet this requirement, the team is evaluating of a Radio Frequency Beacon Receiver (RFBR) unit with a steerable antenna system
  • The RFBR system collects and records raw data at each frequency with a bandwidth of 500 kHz along with processed data sets including \( S_4 \), \( \sigma_\phi \), and TEC in real-time
FORMOSAT-7 / COSMIC-2 RF Beacon

- The first RFBR was installed at Kwajalein Atoll with a high gain steerable antenna prior to launch
- Initial tests were performed tracks of available 400 MHz beacons in polar orbit
- COSMIC-2 launch on 25 June
- Payload Checkout in July
- Beacon instrument cycled (not transmitting)
- Scheduled to begin transmitting on 25 August
• Intention for this talk was to show first COSMIC-2 RF Beacon observations from Kwajalein
  – instead, 400 MHz tone from DMSPF15
• Initial payload checkout slip → transmitting next week
• We’ll be at Kwajalein beginning 07 Sept for RF Beacon checkout
Single look direction to GEO satellite

Increased spatial coverage with beacon

Beacon Data
From 1038 UT Overflight

• Improved scintillation specification
• Six satellites provide ~15 min refresh
• Expanded spatial & temporal coverage
FORMOSAT-7 / COSMIC-2 RF Beacon

RF Beacon System Calibration/Validation

• An extensive Cal/Val effort being coordinated to begin in Sept 2019
• End-to-end validation including development of advanced algorithms to incorporate RF beacon data into real-time ionospheric specification tools
• Multiple RFBR ground sites
• Truth data from ground-based systems & radars
• Cal/Val to include:
  – Evaluation of beacon instrument performance
  – Mapping/Evaluation of spacecraft antenna gain patterns
  – Validation of RFBR observable parameters
Questions?