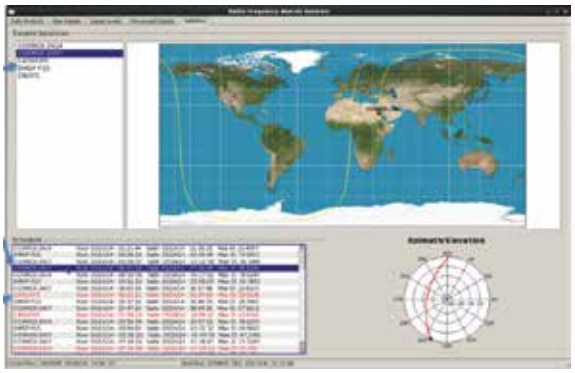
SDL/14-579A

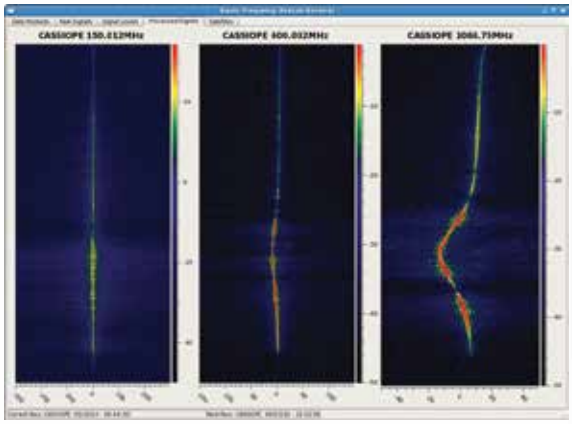
RFBR

RADIO FREQUENCY BEACON RECEIVER

The Space Dynamics Laboratory at Utah State University (SDL/USU), the Air Force Space and Missile Systems Center (SMC), and the Air Force Research Laboratory (AFRL) have teamed together to provide a cost effective, portable ground-based radio frequency beacon receiver (RFBR) system capable of characterizing ionospheric parameters, including total electron content (TEC), and amplitude and phase scintillation. The system, comprised almost entirely of COTS parts, can be configured to receive RF beacons such as those transmitted by existing on-orbit Coherent Electromagnetic Radio Tomography (CERTO) beacons; the upcoming Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC2) beacons; or systems using other frequencies from VHF to S-band. By monitoring the effects of the ionosphere on multiple frequencies, parameters can be derived to determine ionosphere-induced degradation of communication/navigation signals across the electromagnetic spectrum. Additionally, these parameters can then be used by assimilative models to improve ionospheric specifications and forecasts.



Satellite Tracking and Scheduling Display



Processed Signals Display

GROUND-BASED RFBR KEY FEATURES

- Characterizes and derives ionospheric plasma densities in the form of total electron content (TEC), as well as amplitude (S4) and phase (σ_{φ}) scintillation parameters along the signal path
- Scintillation observations estimate ionosphere-induced degradation of communication/navigation signals across the electromagnetic spectrum
- Signal processing algorithms produce the desired data products in real time and package them for local storage as well as transmission to DoD networks
- Software and algorithms are easily reconfigurable in a lab or fielded setting
- Reconfigurable design allows for other beacon frequencies by simply replacing a few components in the RF front end
- Can simultaneously observe several tones spanning VHF to S-band
- Both the RF front end and COTS signal-digitizing hardware are designed and assembled in a way that preserves the phase coherency of the signals
- Can be installed at a remote site, run autonomously, and investigated remotely
- Uses the latest in commercial RF and software-defined radio technology
- Very low cost and portable
- Prototypes can be built in small quantities

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RF ANTENNAS

The RFBR design uses three patch antennas, each optimized for one of the three desired frequencies. The patch antennas are stacked onto a common backing, maintaining phase concentricity, thereby simplifying analysis by removing apparent phase shifts due to zenith angle effects. SDL has tested and can support other antenna designs.

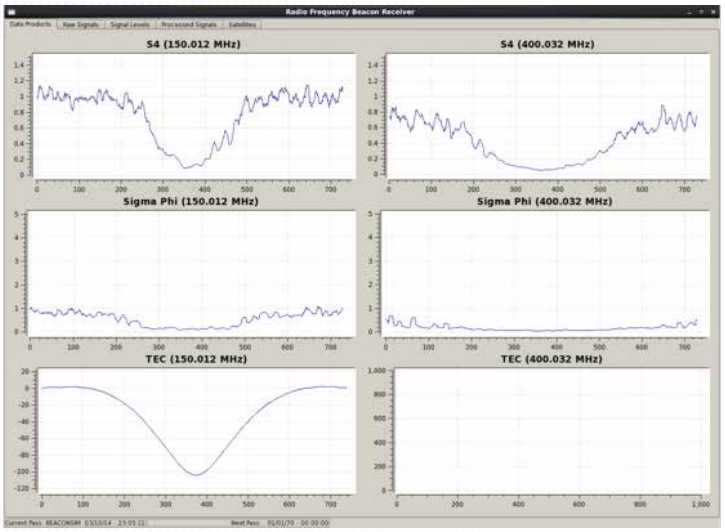
RFBR SYSTEM LEVEL SPECIFICATION

REQUIREMENT ID	SPECIFICATION
Beacon Receiver	Continuous Operation
S4 Range	0 - 1.5
S4 Uncertainty	≤ 0.1 (1σ)
S4 Cadence	≤ 10 seconds
σ_φ Range	0 – 20 rads
σ_φ Uncertainty	≤ 0.1 rads (1σ)
σ_φ Cadence	≤ 10 seconds
TEC Range	0 – 200 TECu
TEC Relative Uncertainty	≤ 0.01 TECu (1σ)
TEC Cadence	≤ 1 second
System Refresh Rate	< 1 minute
View/Reception Angles	~20 to 90° elevation

Specifications are for the RFBR system when tuned to COSMIC2 beacon frequencies. Performance may vary when tuned to other frequencies.

USER INTERFACE

The RFBR user interface allows for real-time inspection of beacon signal integrity, TEC, and scintillation parameter values. All user interface displays pertain to the current overpass data and the values remain displayed until the next overpass starts. Data products are stored on a large local hard drive array in a circular buffer scheme.



PERFORMANCE CHARACTERISTICS OF THE RFBR SOFTWARE

METRIC	PERFORMANCE	INFORMATION
CPU Use	< 20%	This is an average across all 24 logical CPU cores.
Memory Use	< 20%	
Processing Speed	Real Time	All processing is accomplished on a received block of samples from the USRPs prior to the next sample block being received.
Data Storage	Real Time	Raw data, down-sampled processed data, and data products are all written to local storage before the next sample block is received from the USRPs.
Display	Real Time	All displays are updated in real time during overpasses.
Data Product Distribution	1 Hz max (configurable)	Data products can be distributed at the same rate at which they are calculated (1 Hz). The default configuration is to distribute them once per minute to not overload the receiving network.

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