Spectrum Issues Relating to Space Weather Operations

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Definitions

- **ITU-R**: International Telecommunication Union-Radiocommunication Sector
  - Conducts technical work necessary to support WRC decisions
- **WRC**: World Radiocommunciation Conference
  - Regulatory body that modifies/updates International Radio Regulations (treaty-level text)
  - Convenes every 4 to 5 years
  - The number after WRC indicates the year convened
- **SG-RFC**: Steering Group on Radio Frequency Coordination
  - WMO expert group on radio spectrum matters

History

- **March 2014**: WMO Secretariat and NOAA Space Weather Prediction Center (USA) staff requested SG-RFC to take actions gain better protection for RF-based space weather sensors
- **October 2015**: Study Question approved by ITU-R to study space weather sensor spectrum requirements and characteristics
- **November 2015**: WRC-15 placed the topic of space weather sensor protection on the Preliminary Agenda for WRC-23

Why Should You be Concerned?

- Sensors that provide data to support solar event detection and space weather prediction are generally not protected from interference
  - Operating on a non-interference basis
  - Perceived importance of these systems does not overcome regulatory requirements
  - New systems are being planned for many frequency bands that will have priority over your operations
    - First come, first served approach
    - Rarely is an existing user displaced or restricted

Global Benefit

- Limited number of space weather prediction/warning centers
- All centers share data and forecast products – perform a global warning function
- Forecasts and warnings are disseminated widely beyond the countries operating the prediction/warning centers
- Operations critical to protection of infrastructure and significant economic sectors in all countries

How to Fix the Problem?

- Based on request made in March 2014, SG-RFC began the work to gain regulatory protection
  - An international regulatory change can take 8 to 12 years to accomplish
- Complete the technical work to allow WRC-23 to make the required regulatory decisions
  - Implement changes in the International Radio Regulations to provide regulatory recognition and protection
  - Not impose constraints on currently allocated radio services

Roadmap to WRC-19

- The goal is to meet the requirement for WRC-19 to retain the item on the WRC-23 agenda
  - Progress report must be provided to WRC-19 (CPM Report)
    - Deadline for draft elements of that report are due August 2018 – firm deadline
    - Two meetings of ITU-R Working Party 7C will be held prior to August 2018
- WRC-19 may delete or delay (to WRC-27) the agenda item if requirements are not met

Schedule

- WRC-19 to confirm retaining item on WRC-23 Agenda
  - Must document technical and operational characteristics of space weather sensors (*we need to document what we are trying to protect*)
- WRC-23 will consider regulatory changes to provide protection
  - Must study and understand the impact to incumbent users prior to WRC-23 (*cannot impose restrictions on those who had prior regulatory status*)

Importance of Space Weather Monitoring and Prediction

- Space Weather Events may:
  - Disrupt electric power distribution and cause catastrophic damage to distribution equipment
  - Disrupt satellite communications
  - Damage satellites (temporarily or permanently)
  - Increase drag on LEO satellites
  - Reduce GNSS (GPS, GLONASS, Galileo) accuracy and availability
  - Disrupt HF communications
  - Disrupt or damage other electronic and communications systems

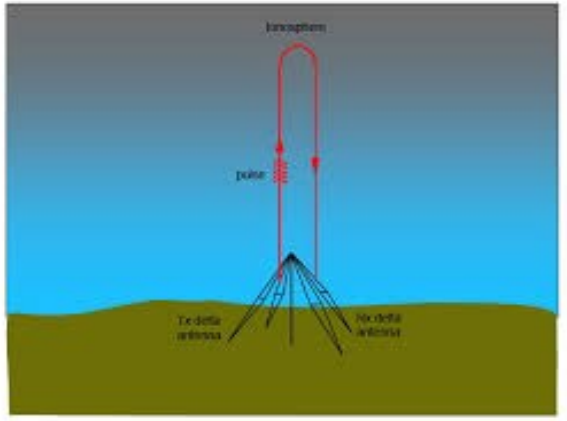
This is a non-exhaustive list of impacts

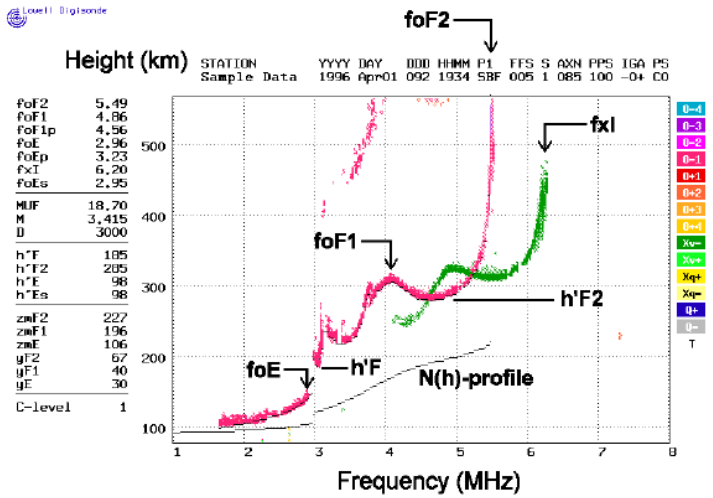
Example Systems

- Active Sensors
  - Ionospheric Sounders
  - Radars
- Passive Sensors
  - Radio Occultation
  - Relative Ionospheric Opacity Meters (Riometers)
  - Solar Flux Monitors
  - Solar Radio Spectrometers

Ionospheric Sounders

- Transmit a swept radio signal into the ionosphere - return signal received at same or different location
- Frequency range typically 1 to 30 MHz
- Provides a direct measure of electron concentration in the ionosphere
- Relatively low power (<500 Watts)



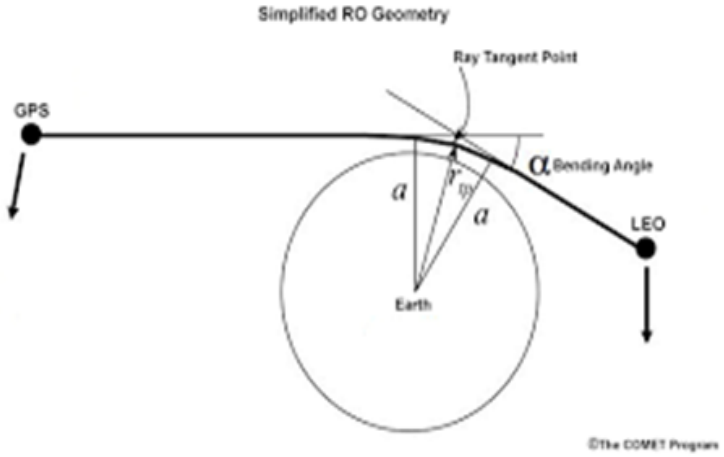


Radars

- Used to measure the ionization and detect plasma instabilities in the ionosphere
- Both coherent and incoherent-type radars used
- Operate in the HF and VHF frequency ranges
- Higher transmit power than ionosondes
- Deployed in limited numbers, however some radars are operated in networks in the polar regions

Radio Occultation

- Satellite-borne or ground based RNSS receiver determines deviation in RNSS signal paths to measure atmospheric and ionospheric properties
- While Radionavigation-Satellite Service (RNSS) signals are used, the operations do not meet the RNSS radio service definition
- Radio occultation use is growing
- Some receivers operate at bandwidths greater than typical RNSS receiver



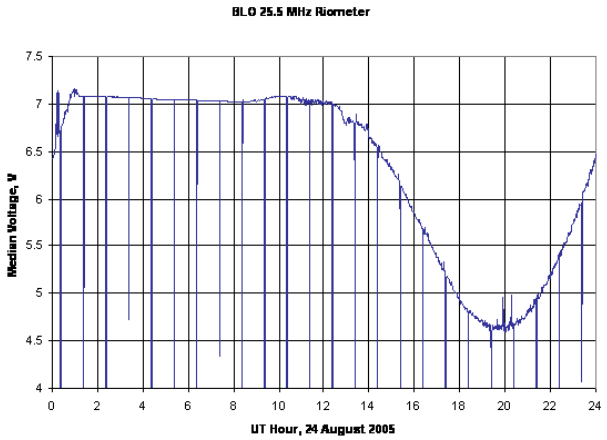
Radio Occultation does not fit the RNSS definition?

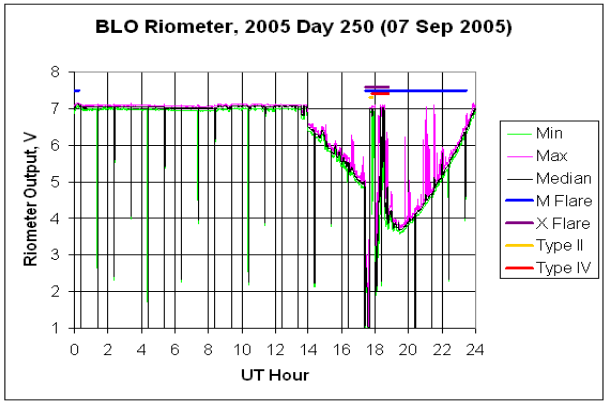
- Radio Occultation receivers process RNSS signals to measure properties of the ionosphere and atmosphere
- Definition of Radionavigation-Satellite Service in the the Radio Regulations: ***A radiodetermination-satellite service used for the purpose of radionavigation***
  - Radionavigation: ***Radiodetermination used for the purposes of navigation, including obstruction warning***
  - Navigation*: ***the method of determining position, course, and distance traveled***

*https://www.merriam-webster.com/dictionary/

Riometers

- Riometers are passive (receive only) systems
- Measure background radio emissions from cosmic sources to determine ionospheric properties
- Show the impact of solar flares on the ionosphere
- Radio Astronomy?





Riometers operate in the Radio Astronomy Service?

- Definition in the Radio Regulations:
  - *radio astronomy:* Astronomy based on the reception of *radio waves* of cosmic origin.
- Riometers receive radio waves of cosmic origin.

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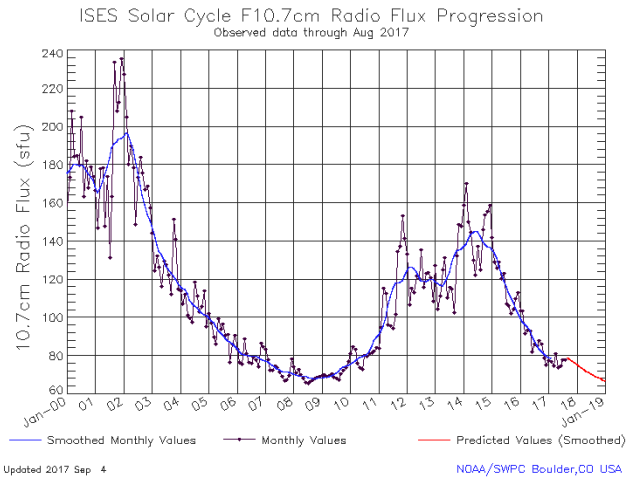
- However, astronomy is defined* as: ***the study of objects and matter outside the earth's atmosphere and of their physical and chemical properties***
- Riometers receive cosmic emissions to study the Sun's impact on the earth's atmosphere

* https://www.merriam-webster.com/dictionary/

Solar Flux Monitors

- Receiver system with high gain antenna pointed at the Sun
- Measure naturally occurring radio emissions from the Sun
- Measurements conducted at 2800 MHz (10.7 cm flux) since 1947. Currently, 245, 410, and 610 MHz and 1.415, 2.7, 4.99, 8.8, and 15.4 GHz are used to observe the sun 24/7.

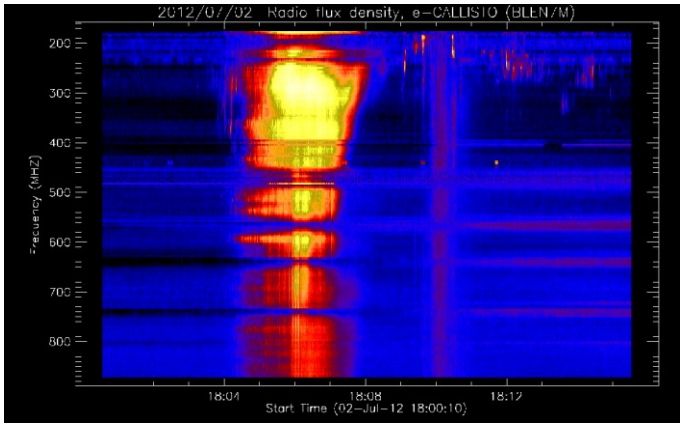


Solar Flux Monitors

- Solar flares are observable as outbursts monitored in the x-ray fluxes observed by satellites and in the radio fluxes observed on Earth.
- These flares indicate solar activity that may include the ejection of material from the solar corona, a solar weather storm which affects the Earth's magnetic field, which in turn produces auroras. In addition, the solar x-rays may cause ionospheric disturbances which affect communications.
- While solar flares are observable in visible light, the x-ray and radio observations do not depend on clear weather over the observatories and are easily measured quantitatively.

Solar Radio Spectrometers

- Spectrographic observations of radio emissions from the Sun's corona
- Typically in the 10 MHz to 2 GHz range
- Can be terrestrial or space-based



Radio Services

- WRC-23 Preliminary Agenda Item 2.3 potentially involves sensor systems operating in multiple radio services
  - Radiodetermination
  - Radio Astronomy
  - Meteorological Aids
  - Earth Exploration-Satellite
  - Space Research
  - Others?

Conclusion

- As spectrum mangers we are learning about these systems, the operations and the science
- Assistance documenting system characteristics and spectrum requirements will be very much appreciated
  - Contributions to ITU-R Working party 7C or to the WMO SG-RFC

- Space weather observations and predictions benefit every administration in the ITU-R and many ITU-R sector members

Thank You!

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Sources

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