Spectrum framework for Lunar PNT: SFCG and ITU related activities

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Workshop on Cislunar Positioning, Navigation, and Timing (PNT)

Outline

- SFCG framework for space missions in the Lunar region
  1. Frequency coordination and assignment for Lunar missions
  2. Guidelines for space missions in the Lunar region
     - Protection of the SZM
     - Frequency allocations and sharing in the Lunar region (SFCG REC 32-2R5)
       - ✓ Frequencies for PNT services
     - Protection of Lunar PNT in 2483.5-2500 MHz
- ITU-R framework for space missions in the Lunar region
  - WRC-27 Agenda 1.15 (new allocations for Lunar communications)

SFCG in a nutshell

Space Frequency Coordination Group (SFCG): created in 1980

- provide a **less formal and more flexible environment** for the solution of frequency management problems encountered by member space agencies;

32 Member agencies all over the world representing the 6 ITU Regional organisations

12 Observers: CCSDS, CEOS, CGMS, CRAF, EUMETNET, IEEE GRSS, **IOAG**, ITU-R SG7, ITWG TOVS/ATOVS, IUCAF, SKAO, WMO

1. **Coordinate the use of individual spacecraft to minimise the interference risk**
2. **Adopt technical/operational recommendations that optimize the use of the space science band**
3. **Agree on common policies and strategies towards potential changes to the ITU Radio Regulations**

Procedures for Inter-Agency coordination and special process for Lunar missions

RES SFCG A12-1R3: Establishment of Procedures for Inter-Agency Frequency Coordination (2008)

- Complement the provisions of the **Article 9** of the ITU Radio Regulations in order to achieve, in a more flexible framework, inter-agency coordination of frequency assignments.
- Provides a template for the **development of bilateral and/or multilateral agreements**

RES SFCG A40-1: Assistance in the Assignment of Frequencies to Missions in the Lunar Region (2022)

- Proper **assignment of frequencies** to lunar missions is essential to mission success;
- The frequency assignment process needs to take into account **interference with lunar missions as well as other near-Earth missions** sharing the same spectrum;
- Interference analysis and frequency selection by one agency for all lunar missions, including frequencies for proximity links, would minimize the potential need for operational coordination;

The **Lunar Spectrum Manager** (LSM, NASA) role has been established to facilitate **more efficient pre-coordination of spectrum requirements** amongst all public- and private-sector lunar activities.

Lunar missions shall coordinate with their respective Frequency Manager, who will liaise with SFCG and the Lunar Spectrum Manager (LSM, NASA), as early as possible during project definition and feasibility phases.

More information on the Lunar Spectrum Management Portal

Guidelines for space missions operating in the Lunar region

Guidelines for Lunar missions		
REC SFCG 32-2R5	**Communication and Positioning, Navigation, and Timing Frequency Allocations and Sharing in the Lunar Region (2023)**	**Reference Recommendation on frequency assignment guidelines for all communications links and PNT in the Lunar Region**
REC SFCG 29-2	Frequency Assignment Guidelines for Active Remote Sensing in the Lunar Region (2009)	Preferred frequencies for the implementation of active sensors in the Lunar region. To be reviewed taking into account the protection of the shielded zone of the Moon.
RES SFCG 23-5R2	**Protection of Future Radio Astronomy Observatories in the Shielded Zone of the Moon (2024)**	**Procedures for cooperation between SFCG Member Agencies and the Radio Astronomy community for the protection of radio astronomy observations in the shielded zone of the Moon**
REC SFCG 14-2R5	Use of the 37-38 GHz Space Research Service Allocation (2004)	Use of the 37-38 GHz planned for Lunar missions.
REC SFCG 41-1	Efficient Spectrum Utilization for Space Research Systems in the Lunar Region (2023)	Guidelines for the implementation of **in-situ lunar links, Earth-space links and space-Earth links** for lunar missions, including spectral emission masks for in-situ lunar links.
REC SFCG 42-1	Frequency channel plan for in-situ lunar data relay satellites (2024)	Channel plan to support interoperability for the **operation of lunar data relay services** in the S-band and the Ka-band
Prov REC SFCG 43-1	**Protection of in-situ lunar region PNT services in the 2 483.5 – 2 500 MHz frequency band from unwanted emissions from lunar surface communications systems (2024)**	**Defines a limit for the aggregate unwanted emissions from each lunar surface wireless system into the frequency range 2483.5 – 2500 MHz for the protection of PNT receivers**

Protection of Radio Astronomy in the SZM

RES SFCG 23-5R2: Protection of Radio Astronomy Observations in the Shielded Zone of the Moon (2024)

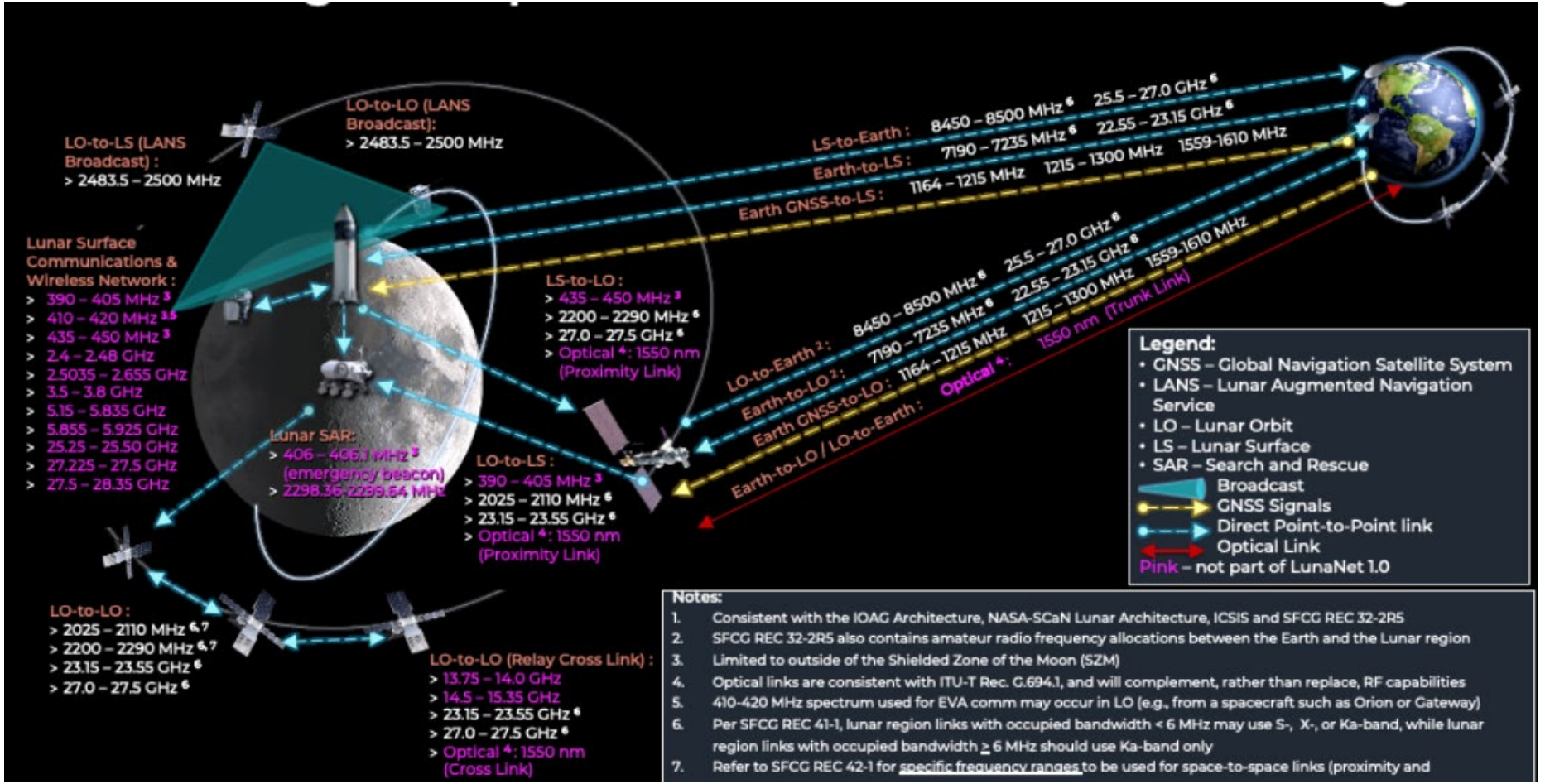
- Procedures for cooperation between SFCG Member Agencies and the Radio Astronomy community for the protection of radio astronomy observations in the shielded zone of the Moon.
- SZM: comprises the area of the Moon's surface and an adjacent volume of space which are shielded from emissions originating within a distance of 100 000 km from the centre of the Earth (ITU RR No. **22.22.1**).

- **Principles for the SZM protection:** Radio Regulations, Article No. **22.22 -** prohibition of emissions causing harmful interference to radio astronomy and other passive services in the full spectrum

- **Exception**: frequency bands allocated to services supporting space research communications (RR Nos **22.23** and **22.24**).
- For the submission of filing to the ITU, satellite networks orbiting around the Moon shall provide a description of the method used to comply with **Articles 22.22 to 22.25**.
- ITU-R Recommendation RA.479-5, "Protection of frequencies for radioastronomical measurements in the shielded zone of the Moon", recommends that **frequencies below 2 GHz be reserved for the use of radio astronomy systems in the SZM**

Frequency allocations and sharing in the Lunar region

REC SFCG 32-2R5 : Communication and Positioning, Navigation and Timing (PNT) Frequency Allocations and Sharing in the Lunar Region (June 2023)



From LunaNet Interoperability Specification Document, version 5

Frequency allocations and sharing in the Lunar region

REC SFCG 32-2R5 :

First version approved in 2012, extensively reviewed since 2019 to address:

- Increased spectrum demand and evolved communications architecture,
- Identification of additional spectrum for broadband surface wireless network,
- Identification of frequency bands for in-situ lunar Positioning, Navigation and Timing and Search and Rescue beacons,
- Protection of Radio Astronomy in the Shielded Zone of the Moon (SZM).

Future revisions planned to accommodate new requirements.

It includes:

- Recommended frequency bands for the various links required for communications and PNT in the Lunar Region
- Provisions for the sharing between different applications and for the protection of the SZM
- For each of the possible links, description of the planned service requirements and possible limitations.

Frequencies for PNT services (REC SFCG 32-2R5)

2483.5-2500 MHz: Core band recommended by SFCG for In-situ lunar PNT

Link	Frequency	
In-situ Lunar based RNSS/RDSS to Lunar Orbit and Lunar Surface	**2483.5-2500**	MHz

Link Type	Frequency Band	Users	Service Type	Typical Data Rate per User	Limitations
9.0 In-situ Lunar based RNSS/RDSS to Lunar Orbit and Lunar Surface	2483.5-2500 MHz (LO-LS)	Rover-Orbiter, EVAs-Orbiter, Surface hubs (Hab, Landers, etc) – Orbiter	PNT	500 bps	Limited to one way PNT transmissions from LO to LS and LO to Low Lunar Orbit (LO to LLO)

- L-band frequencies used for Earth-based RNSS (1164-1215, 1215-1300,1559-1610 MHz) **discarded for In-situ lunar PNT for the protection of the SZM** (bands below 2 GHz)
- Studies on the band 5010-5030 MHz: **not selected by SFCG** – Protection of the Radio Astronomy continnum observation in the 4990-5000 MHz band.

Frequencies for PNT services (REC SFCG 32-2R5)

Link	Frequency	
Earth-based GNSS to Lunar Orbit and Lunar Surface	1164-1215 1215-1300 1559-1610	MHz MHz MHz

Link	Frequency
Lunar Search and Rescue (LunaSAR) beacon	406 – 406.1 MHz (Outside SZM) 2298.36 – 2299.64 MHz (Anywhere)

PNT information may also be contained in:

- signals (e.g. integrated ranging) transmitted in TT&C frequency bands
- Signals integrated in the lunar surface communications

Protection of Lunar PNT in 2483.5-2500 MHz

- Provisions for **the adjacent band compatibility** between Lunar Surface communications in 2400-2480 MHz and 2503.5-2655 MHz and Lunar PNT in the band 2483.5-2500 MHz in **REC SFCG 32-2R5:**
  - 2480-2483.5 MHz and 2500-2503.5 MHz are considered as **guard bands**.
  - Sufficient **OOB filtering** to protect the 2483.5-2500 MHz LO-to-LS PNT band is necessary for lunar surface communications in 2400-2480 MHz and 2503.5-2655 MHz.
- **Protection of In-Situ Lunar PNT in the 2 483.5 – 2 500 MHz band from unwanted emissions from Lunar Surface Communications Systems, SFCG Prov REC 43-1** (For final approval at SFCG-44, June 2025),
  - Defines **a limit for the aggregate unwanted emissions** from each lunar surface wireless system into the frequency range 2483.5 – 2500 MHz for the protection of PNT receivers

1. that the maximum aggregate unwanted emissions into the frequency range 2483.5 – 2500 MHz from each lunar surface wireless system is limited to -121 dB(W/m^2/MHz) at the input of the PNT receive antenna;

2. that lunar surface PNT receiver RF front end operating in the 2 483.5 – 2 500 MHz band have sufficient filtering of signals in the adjacent bands to avoid saturation.

ITU-R framework for space missions in the Lunar region

Lunar communications fall with the **Space Research Service (SRS)**. Some frequency bands allocated to the **Inter-satellite service (ISS)** are also suitable

space research service: A *radiocommunication service* in which *spacecraft* or other objects in space are used for scientific or technological research purposes.

inter-satellite service: A *radiocommunication service* providing links between artificial *satellites*

- Bands currently allocated to SRS **potentially available for lunar communications and PNT**
  - 410-420 MHz (s-s)
  - 2025-2110 MHz (E-s) (s-s) / 2200-2290 (s-E) (s-s)
  - 7190-7235 MHz (E-s) / 8450-8500 MHz (s-E)
  - 13.75-14 GHz / 14.5-15.35 GHz
  - 22.55-23.15 GHz (E-s) / 25.5-27 GHz (s-E)
  - 40-40.5 GHz (E-s) / 37-38 GHz (s-E)
- Bands currently allocated to ISS **potentially available for space-space lunar comms and PNT**
  - 22.55-23.15, 23.15-23.55 GHz / 25.25-25.5, 25.5-27, 27-27.5 GHz

All bands identified in **SFCG REC 32-2R5** for **Earth-Moon links**, for **lunar orbit to lunar orbit** and for **lunar relay cross links** have allocations but….

No suitable allocation for most bands envisaged for **lunar surface applications** and some bands for links between **lunar surface and lunar orbits** (e.g. 2483.5-2500 MHz)

WRC-27 Agenda 1.15 (new allocations for Lunar communications)

AI 1.15:

- possible new or modified **space research service (space-to-space)** allocations, **for future development of communications on the lunar surface and between lunar orbit and the lunar surface**, in
  - 390-406.1 MHz, 420-430 MHz and 440-450 MHz, limited to outside the SZM
  - 2 400-2 690 MHz, 3 500-3 800 MHz, 5 150-5 570 MHz, 5 570-5 725 MHz, 5 775-5 925 MHz, 7 190-7 235 MHz, 8 450-8 500 MHz and 25.25-28.35 GHz;
- Initiate studies on spectrum requirements for lunar communications beyond space research

Background

- All bands identified in **SFCG Recommendation 32-2R5** for Earth-Moon links, for lunar orbit to lunar orbit and for lunar relay cross links have appropriate allocations in the Radio Regulations but….
- No suitable allocation for most bands envisaged for lunar surface applications and some bands for links between lunar surface and lunar orbits

Without ITU allocations in the relevant frequency bands, Space missions can operate and be filed under **RR Article 4.4**: shall **not cause harmful interference to**, and **shall not claim protection from** harmful interference caused by, a station operating in accordance with the provisions of the RR

Objective: obtain new SRS (space-to-space) allocations to get regulatory protection for spectrum usage around the Moon already recognised by SFCG (e.g. **2483.5-2500 MHz for lunar PNT**)

WRC-27 Agenda 1.15 (new allocations for Lunar communications)

Preparatory activities

- Lead group: ITU-R WP 7B
- Definition of SRS characteristics and use cases for lunar applications: generally consistent with SFCG Recommendations and LunaNet specifications
- Compatibility studies between lunar SRS and other services to be started in 2025

Frequency Band	Lunar Surface to Lunar Surface	Lunar Orbit to Lunar Surface	Lunar Surface to Lunar Orbit
390-405 MHz *		X	
406-406.1 MHz *			X
420-430 MHz *	X		
440-450 MHz *			X
2400-2483.5 MHz	X		
2483.5-2500 MHz		**X**	
2500-2690 MHz	X		
3500-3800 MHz	X		
5150-5570 MHz	X		
5570-5725 MHz	X		
5725-5855 MHz	X		
5855-5925 MHz	X		
7190-7235 MHz		X	
8450-8500 MHz			X
27.5-28.35 GHz	X		

* Outside of the Shielded Zone of the Moon.

Thanks for your attention

Questions?

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