The Future of Lunar Spectrum Allocations: Update from ITU-R Working Party 7D

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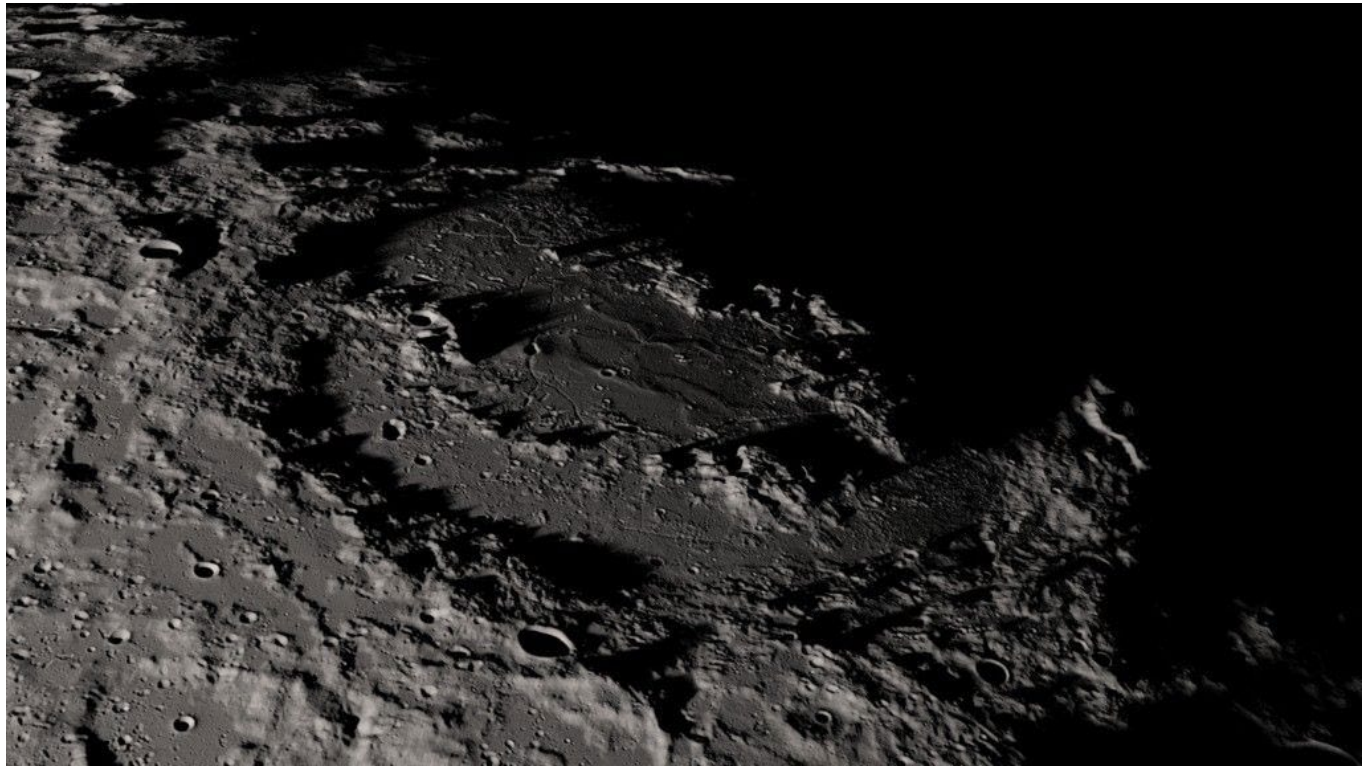
Overview

- Background
  - The unique lunar environment
  - ITU and the current Radio Regulations and Recommendations
  - ITU-R Working Party 7D – Radio Astronomy
- Recent documents and progress at ITU-R Working Party 7D
  - Work directly related to radio astronomy from the Moon
  - Related work on protections for radio astronomy

The Unique Lunar Environment

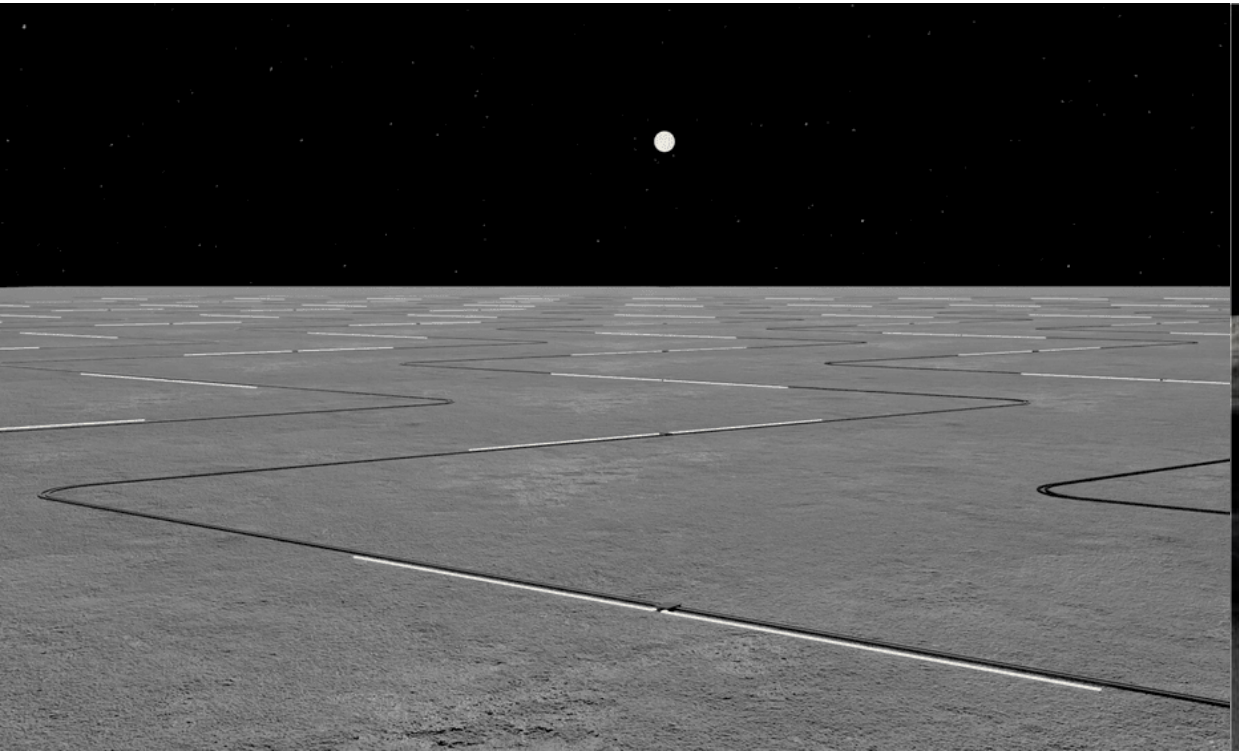
The unique lunar environment has access to parts of the electromagnetic spectrum not available from Earth.

- No atmosphere
  - No absorption by water, oxygen
  - No ionospheric cutoff
- Minimal activity to cause interference
- A shielded zone that further shields from Earth-based RFI and natural auroral radiation
- Especially unique access to frequencies below 2 GHz



The far side of the Moon from the Lunar Reconnaissance Orbiter (image credit: NASA)

NASA’s Vision for the Moon



Both figures are artist’s renderings from NASA

Lunar Day and Night

- One rotation of the Moon is about 28 Earth days.
- During each 14-day lunar night, the surface of the Moon is not exposed to the Sun.
- This long lunar night is an extreme environment with temperatures plummeting below -100 C.

Source: NASA

The shielded zone of the Moon

Figure from Masatoshi Ohishi

RFI Suppression at 100 kHz

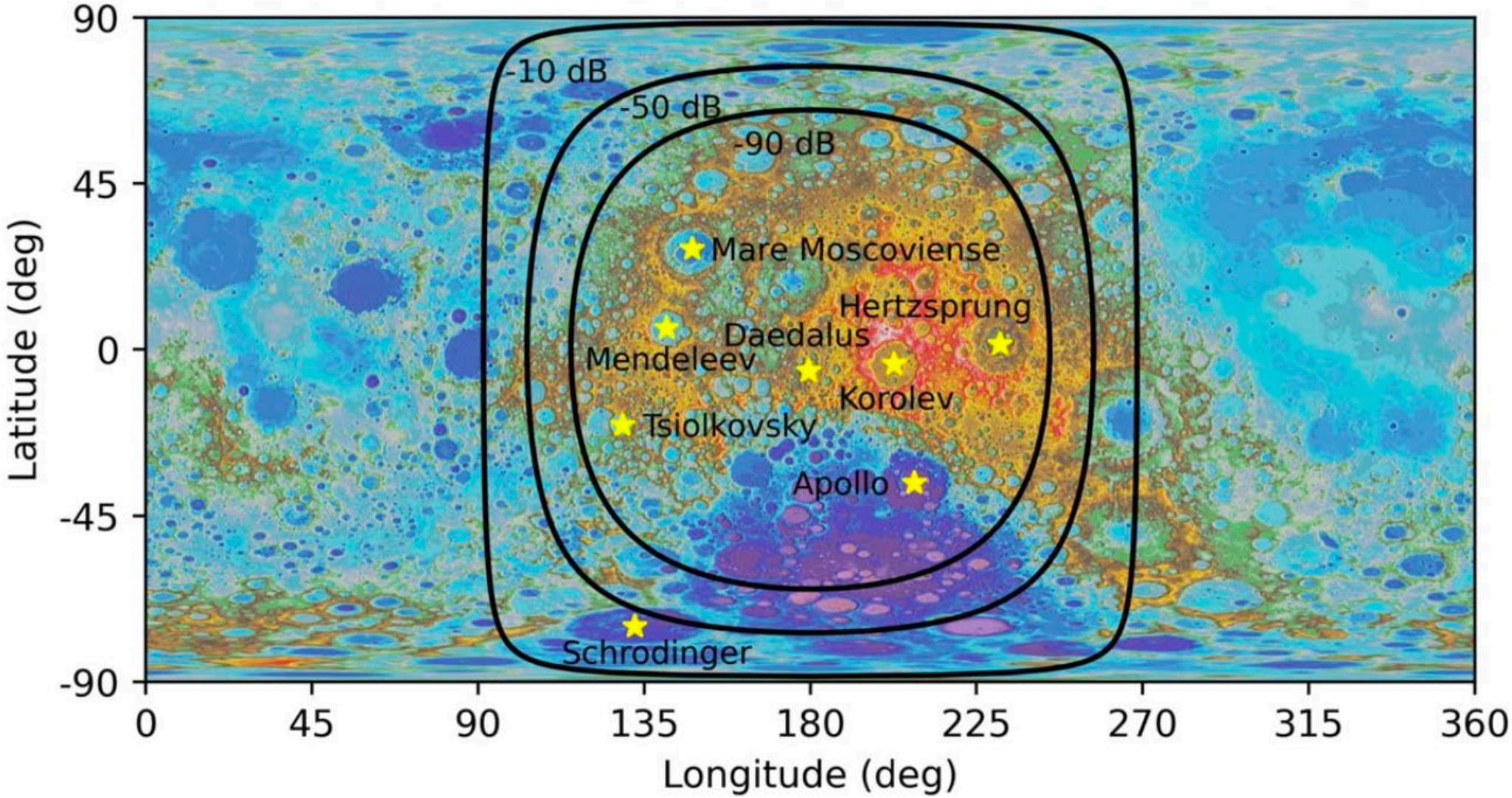
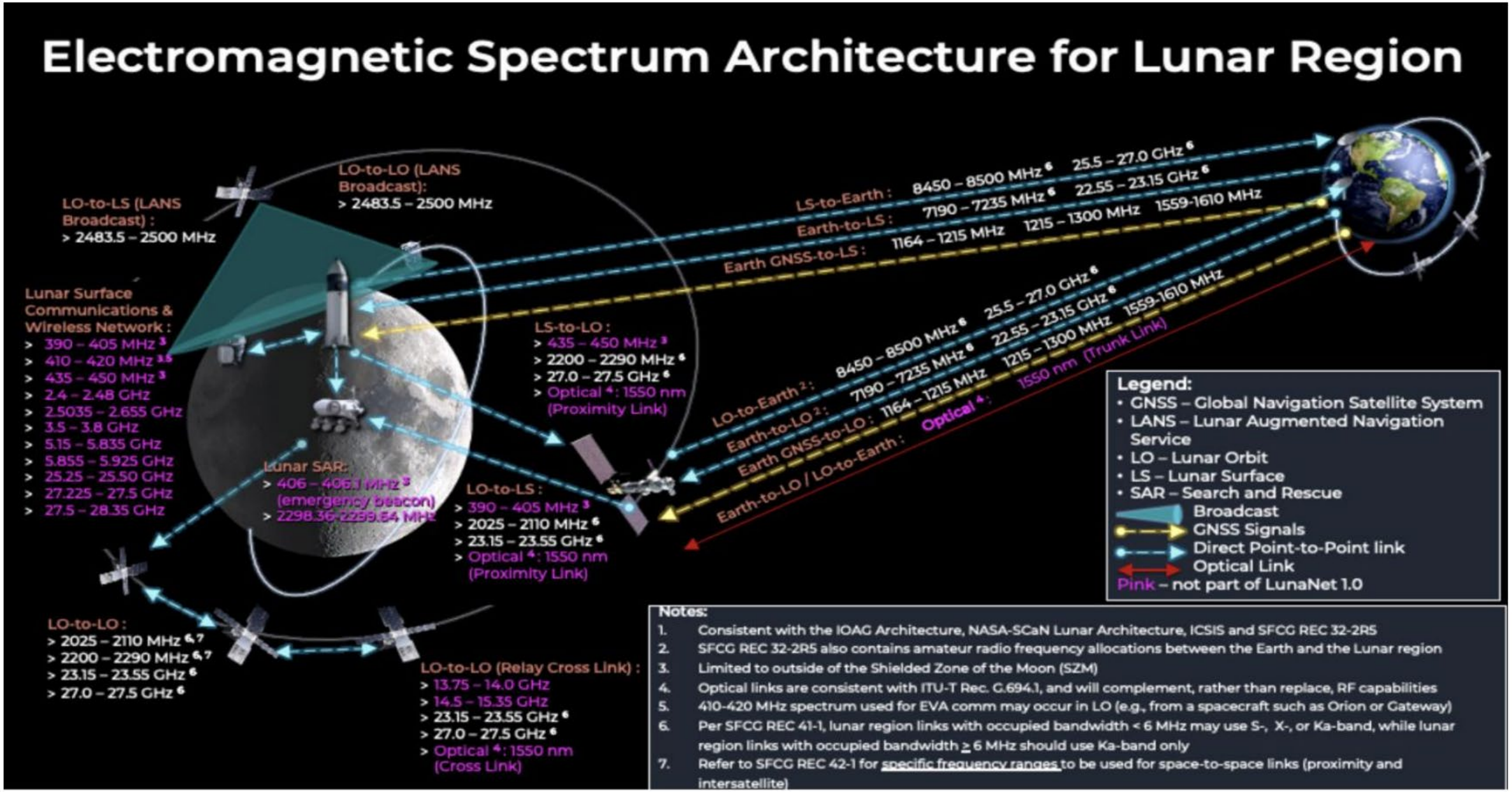


Figure from PDNR ITU-R [SZM_FAC], adapted from Burns *et al.* 2021

Current regulation of lunar spectrum use

- The International Telecommunications Union's Radiocommunication Sector (ITU-R) manages use of the radio spectrum through the Radio Regulations, an international treaty.
- Current definitions group anything not on Earth together
  - Any non-terrestrial radiocommunications are space radio services
  - Any non-terrestrial location is a satellite
- Lunar and cislunar spectrum use is current considered a satellite network or non-geostationary orbit usage by space radio services



NASA's LunaNet Interoperability Specification Version 5, 2025

https://www.nasa.gov/wp-content/uploads/2025/02/lunanetinteroperability-specification-v5-baseline.pdf?emrc=606f9

The current ITU-R Radio Regulations

Section V – Radio astronomy in the shielded zone of the Moon

22.22 § 8 1) In the shielded zone of the Moon[31] emissions causing harmful interference to radio astronomy observations[32] and to other users of passive services shall be prohibited in the entire frequency spectrum except in the following bands:

22.23 *a)* the frequency bands allocated to the space research service using active sensors;

22.24 *b)* the frequency bands allocated to the space operation service, the Earth exploration-satellite service using active sensors, and the radiolocation service using stations on spaceborne platforms, which are required for the support of space research, as well as for radiocommunications and space research transmissions within the lunar shielded zone.

22.25 2) In frequency bands in which emissions are not prohibited by Nos. **22.22** to **22.24**, radio astronomy observations and passive space research in the shielded zone of the Moon may be protected from harmful interference by agreement between administrations concerned.

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[30] **22.19.1** Transmitting antennas of space stations in the broadcasting-satellite service operating in the band 11.7-12.7 GHz are not subject to these provisions but shall maintain their pointing accuracy in accordance with § 3.14.1 of Annex 5 to Appendix **30**.

[31] **22.22.1** The shielded zone of the Moon 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.

[32] **22.22.2** The level of harmful interference is determined by agreement between the administrations concerned, with the guidance of the relevant ITU-R Recommendations.

RECOMMENDATION ITU-R RA.479-5*, **

Protection of frequencies for radioastronomical measurements in the shielded zone of the Moon

recommends

1 that, in planning the use of the radio spectrum, both nationally and internationally, account be taken of the need to provide for radio astronomy observations in the SZM;

2 that, in taking account of such a need, special attention should be given to those frequency bands in which observations are difficult or impossible from the surface of the Earth;

3 that the frequency spectrum should be used in the SZM in keeping with the preliminary guidelines contained in Annex 1;

4 that special attention be paid to emissions into the SZM from deep-space platforms, satellites in the halo orbits near the Sun-Earth L_2 point, satellites in the Earth-trailing orbits, or transmitters near or on the Moon;

5 that in the frequency bands which would be considered for joint use by active and passive space stations in the SZM, radio astronomy observations should be protected from harmful interference. To this end appropriate discussions between concerned administrations may be conducted;

6 that in-situ radiocommunication equipment developed for the environment of Mars or other planets should not be deployed in the SZM, but the choice of frequencies for the close proximity links in the SZM should follow the preliminary guidelines contained in Annex 1.

QUESTION ITU-R 260/7

Radio astronomy in the shielded zone of the Moon

(2022)

decides that the following Question should be studied

1 What are the anticipated scientific characteristics of radio astronomy in the SZM that define the technical and operational characteristics of radio astronomical observations in the SZM, and which frequency bands are expected to maximize the scientific output?

2 How does the lunar environment affect radio astronomy observations in the shielded zone of the Moon?

3 What support systems are anticipated to be needed for conducting radio astronomy observations in the SZM and how may their impact be avoided, especially for frequency bands referred to in *decides* 1?

further decides

1 that the results of the above studies should be included in one or more Recommendations, Reports and/or Handbooks;

2 that the above studies should be completed by 2027.

RESOLUTION 680 (WRC-23)

Studies on frequency-related matters, including 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

The World Radiocommunication Conference (Dubai, 2023),

considering

a) that there is increased interest in conducting scientific discovery and space exploration activities in lunar orbit and on the lunar surface;

b) that wireless communication technology is well-developed and widely deployed on the Earth and could be applied to lunar communications;

c) that point-to-multipoint systems on the lunar surface used for scientific or technological research purposes could operate in the space research service (SRS) (space-to-space) currently;

d) that lunar missions may require signals for accurate Positioning, Navigation and Timing (PNT) in the lunar region originating from Moon-orbiting satellites;

e) that the lunar environment has unique atmospheric, soil and topographic conditions;

f) that the shielded zone of the Moon (SZM) and the absence of appreciable water vapour and oxygen in the lunar atmosphere allow for radioastronomical observations which are not possible on Earth;

g) that the interests of scientific discovery and space exploration are of a global nature;

h) that lunar scientific and exploration activities can advance the development of potential future space activities beyond space research, which may in the future include other relevant radiocommunication services for lunar communications,

noting

a) that Section V of Article **22** addresses protection of radio astronomy in the SZM;

b) that Recommendation ITU-R RA.479-5 relates to the protection of frequencies for radioastronomical measurements in the SZM, with a view to preserving the unique radioastronomical capabilities in this zone;

c) that the impact of unintended electromagnetic radiation from electrical and electronic systems into radio astronomy receivers should be assessed (see Question ITU-R 243/1);

Agenda for the 2027 World Radiocommunication Conference

1.15 to consider studies on frequency-related matters, including 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 accordance with Resolution **680 (WRC-23)**;

SG1 Spectrum management	SG3 Radiowave propagation	SG4: Satellite Services	SG5 Terrestrial Services	SG6 Broadcasting Service	SG7 Science Services
WP1A Spectrum engineering techniques	WP3J Propagation fundamentals	WP4A Efficient orbit/spectrum utilization for FSS and BSS	WP5A Land mobile service above 30 MHz (excluding IMT); wireless access in the fixed service; amateur and amateur-satellite services	WP6A Terrestrial broadcasting delivery	WP7A Time signals and frequency standard emissions
WP1B Spectrum management methodologies and economic strategies	WP3K Point-to-area propagation	WP4B Systems, air interfaces, performance and availability objectives for FSS, BSS and MSS, including IP-based applications and satellite news gathering	WP5B Maritime mobile service including Global Maritime Distress and Safety System (GMDSS); aeronautical mobile service and radiodetermination service	WP6B Broadcast service assembly and access	WP7B Space radiocommunication applications
WP1C Spectrum monitoring	WP3L Ionospheric propagation and radio noise	WP4C Efficient orbit/spectrum utilization for MSS and RDSS	WP5C Fixed wireless systems; HF and other systems below 30 MHz in the fixed and land mobile services	WP6C Programme production and quality assessment	WP7C Remote sensing systems
	WP3M Point-to-point and Earth-space propagation		WP5D IMT Systems		WP7D Radio astronomy

Slide from Jonathan Williams (NSF)

March 2026 Working Party 7D Delegation

- Ashley VanderLey** (HoD)
- Jonathan Williams**(Deputy HoD)
- Rob Avery, NTIA**
- Greg Baker, FCC**
- Darcy Barron, UNM
- Hastyar Barvar, Amazon
- Sarah Marie Bruno, Villanova University
- Roohi Dalal, AAS
- Elena Dejaco, NASA
- Judy Deng, SES
- Chris DePree, NRAO
- Jeff Devereux, NTIA
- Kellen Gibson
- Eric Grodsky, FCC
- Christine Hackman, NRL
- Shelli Rose Haskins, NTIA**
- Greg Hellbourg, Caltech
- Dante Ibarra, FCC**
- Don Jansky, Consultant
- George John, Hogan Lovells
- Damon Ladon, Wiltshire Grannis
- Ryan McDonough, NASA
- Andrew Meadows, NTIA
- Mike Mullinix, CTIA
- Victory Nguyen, eSimplicity
- Karen O'Neil, NRAO
- Scott Paine, SAO Harvard
- Brian Patten, NTIA**
- Andrew Pegues, State
- Josh Reding, Engineering Specialist
- Frank Schinzel, NRAO**
- Cathy Sham, NASA**
- Philip Sohn, NOAA
- Merissa Velez, Verizon
- Donna Wang, FCC**
- Franz Zichy, HII

** indicates in-person in Geneva

Relevant working documents developed by the US

Report ITU-R [SZM_FAC] –

Radio astronomy facilities on the Moon

Recommendation [SZM_THRESHOLDS] –

Threshold levels of permissible interference to radio astronomy in the shielded zone of the Moon

Report ITU-R RA.[SZM_THRESHOLDS] –

Threshold levels of permissible interference to radio astronomy in the shielded zone of the Moon

Report ITU-R RA.[SZM-DARK_SECTOR] –

Experience gained from RAS operations in Antarctica and applicability to protecting RAS in the SZM and similarly remote environments

Radio astronomy facilities on the Moon

This was successfully advanced to a Preliminary draft new **Report** at the March meeting.

Facilities in the current report include

- **ROLSES** (Radiowave observations at the Lunar Surface of the photoElectron Sheath) - 2024
- FARSIDE (Farside Array for Radio Science Investigation of the Dark ages and Exoplanets)
- Lunar Crater Radio Telescope
- FarView
- LuSEE (Lunar Surface Electromagnetic Experiment)
- TSUKUYOMI
- Astronomical Lunar Observatory and Dark Ages Explorer
- FIRST (Formation-flying sub-Ionpheric Radio Astronomy Science and Technology)
- OLFAR (Orbiting Low Frequency Antennas for Radio Astronomy)

Radio astronomy facilities on the Moon

Quantity	Value
Antennas	128 × 100 m length dipoles (100 kHz – 2 MHz), 128 × 5 m length dipoles (1-40 MHz)
Frequency Coverage	100 kHz – 40 MHz (1400 × 28.5 kHz channels)
Field of View (FWHM)	> 10,000 deg^2
Spatial Resolution	10 degrees @ 200 kHz / 10 arcminutes @ 15 MHz
Antenna efficiency	6.8×10^{-6} @ 200 kHz / 9.5×10^{-5} @ 15 MHz
System Temperature[a,b]	1.0×10^6 K @ 200 kHz / 2.7×10^4 K @ 15 MHz
Effective Collecting Area[c]	~ 12.6 km^2 @ 200 kHz / 2,240 m^2 @ 15 MHz
System Equivalent Flux Density (SEFD)	230 Jy @ 200 kHz / 2.8×10^4 Jy @ 15 MHz
1σ Sensitivity[b] (60 seconds; bandwidth = **ν**/2)	93 mJy @ 200 kHz[d] / 1.3 Jy (1.2 K) @ 15 MHz
1σ Sensitivity[b] (1 hour; bandwidth = **ν**/2)	12 mJy @ 200 kHz[d] / 170 mJy (160 mK) @ 15 MHz
1σ Sensitivity[b] (1000 hours; bandwidth = **ν**/2)	230 μJy[e] @ 200 kHz[d] / 3.8 mJy (5.2 mK) @ 15 MHz

[a] System temperature includes contribution from the sky and ground due to the absence of a ground screen.
[b] These values have been updated from the Astro 2020 report due increased fidelity in the front-end design (see §3.5).
[c] Effective area is impacted by loss of gain into the ground due to absence of a ground screen. Antenna efficiency not included.
[d] Sensitivity calculations at 200 kHz assume night time conditions.
[e] Deep confusion-free integrations are possible < 3 MHz due to the absence of extragalactic sources.

Table of FARSIDE characteristics from report

Threshold levels of permissible interference to radio astronomy in the shielded zone of the Moon

[ELEMENTS FOR A] WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW [GUIDING] RECOMMENDATION [SZM_THRESHOLDS]

Threshold levels of [permissible] interference [detrimental] to radio astronomy in the shielded zone of the Moon

(Question ITU-R 260/7)

(202X)

{Editor's notes:

Working Party 7D has not reached agreement on whether Annex 2 (Background on receiver and sky brightness temperatures) should be included in the Recommendation or Report.

Administrations disagree on the appropriate terminology: harmful vs permissible interference}

Scope

This Recommendation [addresses threshold levels of permissible / provides guidance regarding harmful] interference to radio astronomy in the shielded zone of the Moon [as may be necessary by the unique / given the] restrictions on emissions under Radio Regulations (RR) Nos. **22.22**-**22.25**.

FIGURE 1

Equivalent sky brightness for different models, correcting for ground spill.
The red line represents the suggested sky model.

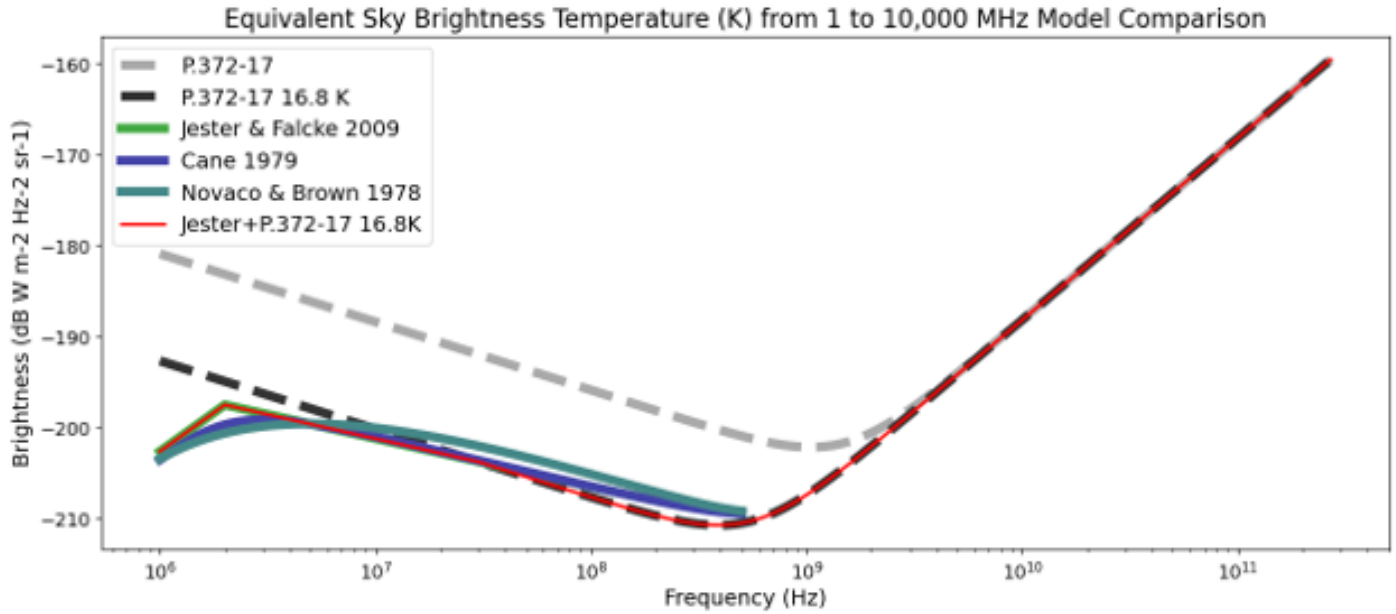


TABLE 1

[Formula for calculating nominal levels of permissible interference to wideband (continuum) / Wideband (continuum) threshold values of interference harmful to] radio astronomy observations in the shielded zone of the Moon

Frequency f (Hz)	Bandwidth $h\Delta f$ (Hz)	Minimum antenna noise temperature T_A (K)	Receiver noise temperature T_R (K)	System sensitivity (noise fluctuations)		Threshold interference levels		
				Rms noise temperature ΔT (K)	Power spectral density ΔP_S (W Hz^{-1})	Input power ΔP_H (W)	Incident pfd $\Delta P_H (\lambda^2/4\pi)^{-1}$ (W m^{-2})	Spectral pfd S_H (W m^{-2} Hz^{-1})
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
f	$r_w f$ r_w see Table 3	Table 3	Table 4	$(T_A+T_R)(\Delta f \Delta t)^{-1/2}$ Δt see Table 3	$r_{fn}\, k_B\, \Delta T$ r_{fn} see Table 3	$\Delta P_S\, \Delta f$	$\Delta P_S\, \Delta f\, 4\pi (cf^{-1})^{-2}$	$\Delta P_S\, 4\pi\, (cf^{-1})^{-2}$

TABLE 3

Frequency-independent relations, parameters, and constants

Quantity	Symbol	Unit	Value/Expression
Fraction of bandwidth used for wideband observations	r_w	–	0.25 (See[1])
Fraction of bandwidth used for narrow band observations	r_n	–	3.3×10^{-6} (See[2])
Minimum antenna noise temperature	T_A	K	$(1-f_g)\ T_S + f_g\ T_G$
Fraction of ground radiation spilling into antenna	f_g	–	0.1
Minimum sky brightness temperature	T_S	K	$T_S = (T_{f0}-T_{CMB})(f f_0^{-1})^{\beta} + T_{CMB}$
Minimum ground temperature during lunar night	T_G	K	26
Reference sky brightness temperature	T_{f0}	K	Table 4
Brightness temperature of the Cosmic Microwave Background	T_{CMB}	K	2.73
Reference frequency	f	Hz	Table 4
Spectral index	β	–	Table 4
Minimum sky temperature at reference frequency	T_{f0}	K	Table 4
Integration time	Δt	s	1.2×10^6
Tolerable fraction of noise temperature	r_{fn}	–	0.1 (See[3])
Boltzmann constant	k_B	J K^{-1}	1.38×10^{-23}
Speed of light	c	m s^{-1}	3.00×10^8

Working Party 7D

LIAISON STATEMENT TO WORKING PARTY 7B

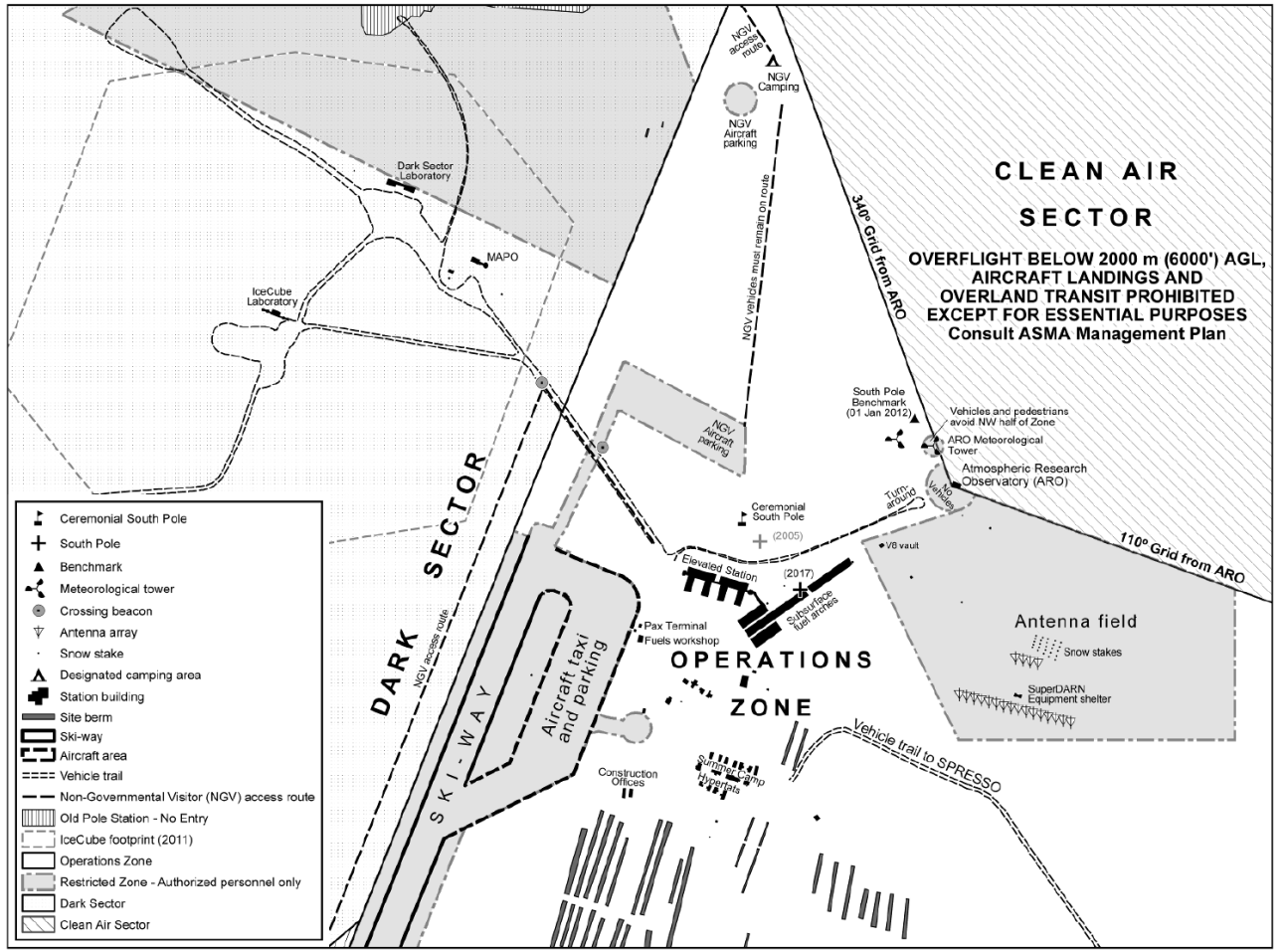
Clarification on threshold levels of interference to radio astronomy in the shielded zone of the Moon

- Addresses concerns on thresholds for emissions outside of bands allocated to Space Research Service (SRS)
- Notes that assumed integration time is the duration of the lunar night: 1.2 million seconds
- Notes that in-band emission exceeding saturation thresholds will drive LNAs into the non-linear domain
- Notes thresholds for damaging receivers from ITU-R RA.2188

Experience gained from RAS operations in Antarctica and applicability to protecting RAS in the SZM and similarly remote environments

This working draft highlights parallels between Antarctica and the Moon, and describes practices at the Dark Sector of the US South Pole Station.

- Antarctica and the SZM have a similar size, and each offer unique geographical benefits.
- Both regions are without national sovereignty, managed by international treaty (Radio Regulations for SZM, and Antarctic Treaty for Dark Sector).
- Both have a clearly defined “dark period” to prioritize for protection (lunar night, and Antarctic winter)



Related work on protections for radio astronomy

- WRC-27 Agenda Item 1.16 on Radio Ouiet Zones

  1.16 to consider studies on the technical and regulatory provisions necessary to protect radio astronomy operating in specific Radio Quiet Zones, and in frequency bands allocated to the radio astronomy service on a primary basis globally, from aggregate radio-frequency interference caused by non-geostationary-satellite orbit systems, in accordance with Resolution **681 (WRC-23)**;

  RQZ database continues to be updated (including US entries)

- Working Document: Report ITU-R RA.[UEMR] - Radiation from spaceborne electrical equipment into RAS frequency bands
- Report ITU-R RA.2126 - Techniques for mitigation of radio frequency interference in radio astronomy
- Working Document: Report ITU-R RA.[BOLO] - Protection thresholds for background-limited detectors with large fractional bandwidth

Summary

- Protections for radio astronomy from the shielded zone of the Moon exist in the Radio Regulations.
- Many details need to be worked out in order to fully realize these protections as lunar activity ramps up.