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| **Purpose/Objective:** To provide information about the coordination practices in place within and around the Antarctic Dark Sector and how these practices may be relevant to future operations around the Shielded Zone of the Moon (SZM). |
| **Abstract:** This draft new Report is to summarize current practices for spectrum management in Antarctica, especially in the Antarctic Dark Sector, as applicable to radio astronomy operations on the Moon. This new Report will address lessons learned from operations in practice to protect RAS in Antarctica to better inform the future development of lunar operations around the SZM. This input contribution provides updates to the document currently attached to the Chairman’s Report (7D/186 Annex 17). |

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| UPDATES TO Working Document Towards a Preliminary Draft New Report ITU-R RA.[SZM-DARK\_SECTOR] |

**The Applicability of Current Practices to Protect RAS operations in Antarctica to Future Operations Around the Shielded Zone of the Moon**

**Summary**

This draft new Report is to summarize current practices for spectrum management in Antarctica, especially in the Antarctic Dark Sector, as applicable to radio astronomy operations on the Moon. This new Report will address lessons learned from operations in practice to protect RAS in Antarctica to better inform the future development of lunar operations around the SZM. This input contribution provides updates to the document currently attached to the Chairman’s Report (7D/186 Annex 17).

**Attachment**

ATTACHMENT

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| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ITU-R RA.[SZM-DARK\_SECTOR] |
| Lessons learned from RAS operations in Antarctica and applicability to protecting RAS in the SZM and similarly remote environments  |

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# **1 Introduction**

Radio astronomy is a powerful branch of astronomy that studies celestial objects and phenomena by detecting and analysing the radio waves they emit. Radio astronomy has been instrumental in key discoveries, including the cosmic microwave background radiation, the confirmation of gravitational waves, and the distribution of galaxies throughout the universe. However, access to the radio spectrum for these highly sensitive observations from the Earth is constrained by atmospheric absorption as well as artificial terrestrial emissions for radiocommunications. For this reason, astronomers have sited their telescopes in remote locations free from terrestrial emissions and in high altitude, dry climates where atmospheric effects are minimized. Many observatories are located in radio-quiet zones that can utilise government legislation for enforcement. However, some of the sites with the most exceptional conditions for radio astronomy exist in locations without national sovereignty or formal coordination procedures.

One such location is the geographic South Pole in Antarctica. The South Pole’s unique location offers a continuous view of the southern celestial hemisphere, and a stable environment with minimal atmospheric turbulence during austral winter when the Sun sets for six months. The dry, stable atmosphere minimizes interference from water vapor absorption and its fluctuations, allowing telescopes to probe the universe with remarkable precision. Researchers take advantage of these conditions to study the cosmic microwave background (CMB) radiation, a relic of the Big Bang, and to carry out surveys of the distribution of matter across the Universe, providing crucial insights into its origins, structure and evolution. Such studies have been pivotal in refining cosmological models, including constraints on dark matter, dark energy and inflationary theories.

# **2 Scientific investigations including RAS enabled by the Antarctic Dark Sector environment**

{Editor’s note: Content to be developed further. Cooperation practices in place for each telescope/observatory to be addressed here.}

## **2.1 The South Pole Telescope (SPT)**

The South Pole Telescope (SPT) is a state-of-the-art instrument designed to observe the Cosmic Microwave Background (CMB) to explore fundamental questions about the universe’s origin, structure and evolution. Located at the Amundsen-Scott South Pole Station, it benefits uniquely from the Antarctic Dark Sector environment. The telescope site offers exceptionally stable, dry and clear atmospheric conditions due to its high altitude, low humidity and minimal light pollution, all critical prerequisites for making precise millimeter and submillimeter-wave observations. These ideal observing conditions, combined with the restrictions on electromagnetic interference in the Dark Sector, enable the SPT to collect high-fidelity data crucial for studying the early universe.

## **2.2 BICEP/Keck Array**

Alongside the South Pole Telescope, the BICEP (Background Imaging of Cosmic Extragalactic Polarization) and Keck Array experiments are key players in the quest to understand the earliest epochs of the universe. These instruments are designed to detect the faint polarization patterns in the CMB that could provide evidence of cosmic inflation. The success of these scientific endeavors relies heavily on the Antarctic Dark Sector’s extraordinary observing conditions. The region’s stable, dry atmosphere minimizes interference from water vapor. The isolation and protected electromagnetic environment of the Dark Sector further ensure the integrity of ultra-sensitive measurements.

## **2.3 The IceCube Neutrino Observatory**

The IceCube Neutrino Observatory, buried deep in the Antarctic ice near the South Pole, represents a revolutionary approach to exploring the universe through neutrinos, subatomic particles that can travel vast distances without being absorbed or deflected. By embedding more than 5,000 digital optical modules over a cubic kilometer of extremely clear glacial ice extending to a depth of about 2,500 meters, IceCube captures the rare flashes of light produced when neutrinos interact with the ice. The Antarctic environment is uniquely suited for this kind of detector as the ice provides both the massive detection volume and the extraordinary optical clarity necessary for observing these fleeting events. The remote location and infrastructure of the Dark Sector also support the precision timing and low-noise operation IceCube requires to track high-energy astrophysical neutrinos back to their cosmic origins.

## **2.4 The Askaryan Radio Array (ARA)**

Complementing IceCube, the Askaryan Radio Array (ARA) is another ambitious South Pole project under construction near the South Pole which aims to detect high-energy neutrinos. Rather than using light, ARA relies on detecting radio pulses generated by neutrino interactions in the ice, a phenomenon known as the Askaryan effect. The detector will be buried about 200 meters deep in the ice. The Antarctic ice is ideal for this technique, offering vast, radio-transparent volumes and extremely low levels of background radio noise. The Dark Sector’s radio-quiet restrictions are especially critical for ARA’s success, as even minor human-made radio interference could drown out the rare signals it seeks to detect. This makes Antarctica not just a practical location but a necessary one for such cutting-edge radio-based neutrino astronomy.

# **3 Processes for Enabling RAS in the Antarctic Dark Sector**

{Editor’s note: Content to be developed. National experiences with cooperation on spectrum usage in Antarctica to be discussed here, including intergovernmental agreements, with a focus on technical lessons learned. Bullet points included for future content development}

– Dark Sector spectrum management practices

– The role of national programs (e.g. US South Pole station & NSF)

– Current coordination processes between passive and active operations in Antarctica

– Lessons learned

The Dark Sector of Antarctica has maintained a radio quiet environment in part due to its remote location at the geographic South Pole, but an important contributing aspect to the success of spectrum management is the naturally limited access to this extremely remote area. This limited access is not the result of any regulation or restriction, but is the result of the remoteness and extreme environment, especially during the austral winter. Any new local transmitters or sources of interference can be traced to a small number of stakeholders and visitors. During the austral winter, travel to and from the South Pole, as well as all air traffic in Antarctica, completely stops. During this period of time, with a limited population at the South Pole station, the radio environment is quiet as well as stable.

# **4 Developing Best Practices for Protecting the SZM and Other Unique Environments for Astronomy**

{Editor’s note: Content to be developed further. Noting that the intent is not to suggest reproducing practices in Antarctica directly to other remote environments such as the Moon, as some lessons learned could inform what ought not be reproduced. The following bullet points are included as placeholders for further elaboration.}

– RR Article **22**

– Recommendation [ITU-R RA.479](https://www.itu.int/rec/R-REC-RA.479/en)

– Compare/contrast Antarctica with the SZM (controlled/limited access, terrestrial vs. space operations, land size, existing regulations & mechanisms, international cooperation, exploitation of natural resources)

Spectrum policies and practices on Antarctica present a practical example of managing extreme environments in support of scientific research, including radio astronomy. These management practices may be highly relevant to informing the development of analogous practices in similarly remote and extreme environments, as civilization and radio astronomy continue to expand and proliferate into new locations including the Moon and deep space. Just as the geographic location of the South Pole offers a unique physical environment, the Shielded Zone of the Moon (SZM) and the L2 Sun-Earth Lagrange Point[[1]](#footnote-1) are two examples of locations with unique characteristics that have enabled radio astronomy.

The Shielded Zone of the Moon (SZM) has been recognized as a location offering a pristine environment for radio astronomy. The SZM, an area somewhat less than half of the lunar surface, is a zone in which passive observations remain unhindered by interference as this part of the Moon’s surface is always facing away from Earth and is therefore shielded from terrestrial and Earth-orbiting radio transmitters. A number of facilities and mission concepts have been proposed including the Radio-wave Observations at the Lunar Surface of the photoElectron Sheath (ROLSES), which already landed and collected data in 2024, and other projects already in development. Lunar-based radio astronomy holds immense potential to address fundamental questions about the universe. While the Radio Regulations (RR) Article **22** provides protection for the radio astronomy service within the SZM, practical mechanisms for implementing spectrum management in the lunar environment will need to be established.

Comparing the Antarctic Dark Sector and the SZM highlights a number of similarities and key differences. Both Antarctica and the Moon are locations without national sovereignty. Both are remote environments with minimal human activity, offering exceptional conditions for radio astronomy due to their natural shielding from electromagnetic interference. However, Antarctica is a terrestrial environment with an extensive regulatory infrastructure, including established enforcement practices, controlled physical access and national presence via research stations. The Moon, by contrast, is a space environment with limited access, no permanent human presence, and less developed regulatory mechanisms. The Moon also offers unparalleled shielding from earth-based radio noise.

For both environments, only a subset of countries have participated and signed on to international treaties[[2]](#footnote-2). Special protections for radio astronomy have been implemented through the designation of the “Dark Sector” at the Amundsen-Scott South Pole Station. This sector is subject to restrictions on electromagnetic emissions. Compliance is facilitated through equipment reviews, careful station planning, and close coordination among researchers. However, enforcement of a radio-quiet environment within the shielded zone of the Moon may be more complex[[3]](#footnote-3). On the Moon, compliance is largely guided by Recommendation ITU-R RA.479, which recognizes the value of preserving the SZM for radio astronomy. Furthermore, Article 22 of the ITU Radio Regulations relies on multilateral discussion among states.

International cooperation remains essential in both domains. On the Moon, efforts are still emerging, with proposed norms around the SZM dependent on future agreements among spacefaring nations. Ultimately, Antarctica serves as a mature model of collaborative scientific governance with enforceable protections, whereas the Moon represents a frontier where such mechanisms are under development. The future of radio astronomy in the lunar environment will depend on whether lessons of the Antarctic Dark Sector can be meaningfully adapted to the vastly different legal and operational realities of the Moon.

# **5 Summary**

{Editor’s note: Summary to be written upon completion of the Report }

TBD

# **6 Related ITU-R Recommendations/Reports**

Recommendation [ITU-R RA.314](https://www.itu.int/rec/R-REC-RA.314/en) – *Preferred frequency bands for radio astronomical measurements*

Recommendation ITU-R RA.479 – *Protection of frequencies for radioastronomical measurements in the shielded zone of the Moon*

Recommendation ITU-R RA.1417 – A Radio Quiet Zone in the vicinity of the L2 Sun-Earth Lagrange point

{Editor’s note: Report ITU-R RA.[SZM-FAC] is under development}

Report ITU-R RA.[SZM-FAC]

# **7 Abbreviations/Glossary**

SPT South Pole Telescope

RFI Radio Frequency Interference

RR Radio Regulations

SZM Shielded Zone of the Moon

CMB Cosmic Microwave Background

1. See Recommendation ITU-R RA.1417. [↑](#footnote-ref-1)
2. Antarctica is governed under the Antarctic Treaty, which designates the continent for peaceful purposes including scientific investigation. The Moon falls under the jurisdiction of the 1967 Outer Space Treaty, which similarly promotes peaceful exploration and prohibits national appropriation but does not provide direct regulatory mechanisms. [↑](#footnote-ref-2)
3. Antarctica is protected from resource exploitation under the Madrid Protocol, whereas lunar activities are trending towards commercial development. [↑](#footnote-ref-3)