WP 7D report
Agenda items 1.16 and 1.18

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07 April, 2025

Image credit - European Southern Observatory

AI 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)

- the Square Kilometre Array Observatory in South Africa
- the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile

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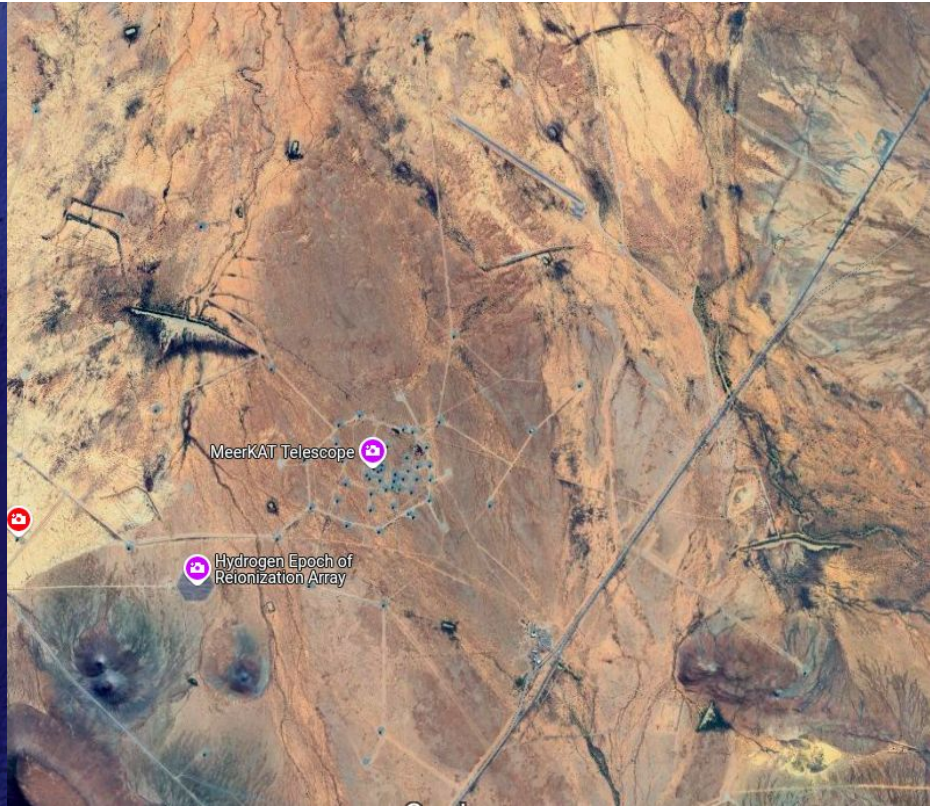
TABLE 1

RAS frequency bands to be studied and corresponding active services to be included

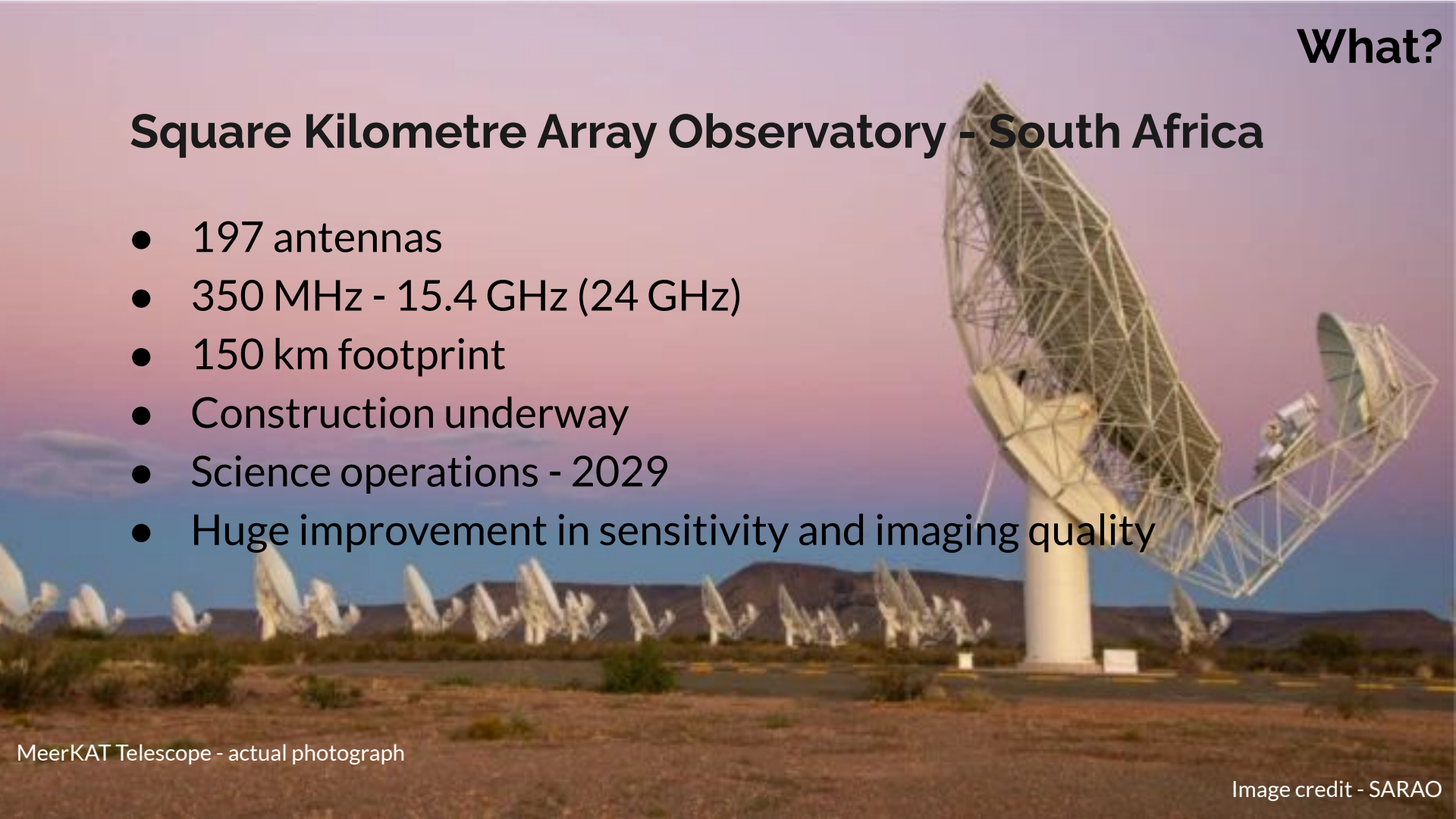
Radio astronomy frequency band	Active space service operating in adjacent or nearby frequency band	Active space service (space-to-Earth)	Scope
10.6-10.7 GHz	10.7-10.95 GHz	FSS	*Resolves etc.* 1 and 2
42.5-43.5 GHz	42-42.5 GHz	FSS	*Resolves etc.* 2
76-77.5 GHz	74-76 GHz	FSS, MSS	*Resolves etc.* 2
94.1-95 GHz	95-100 GHz	RNSS, MSS	*Resolves etc.* 2
100-102 GHz	95-100 GHz	RNSS, MSS	*Resolves etc.* 1 and 2
114.25-116 GHz	116-119.98 GHz	ISS	*Resolves etc.* 1 and 2
130-134 GHz	123-130 GHz	FSS, MSS, RNSS	*Resolves etc.* 2

Square Kilometre Array Observatory - South Africa



Square Kilometre Array Observatory - South Africa

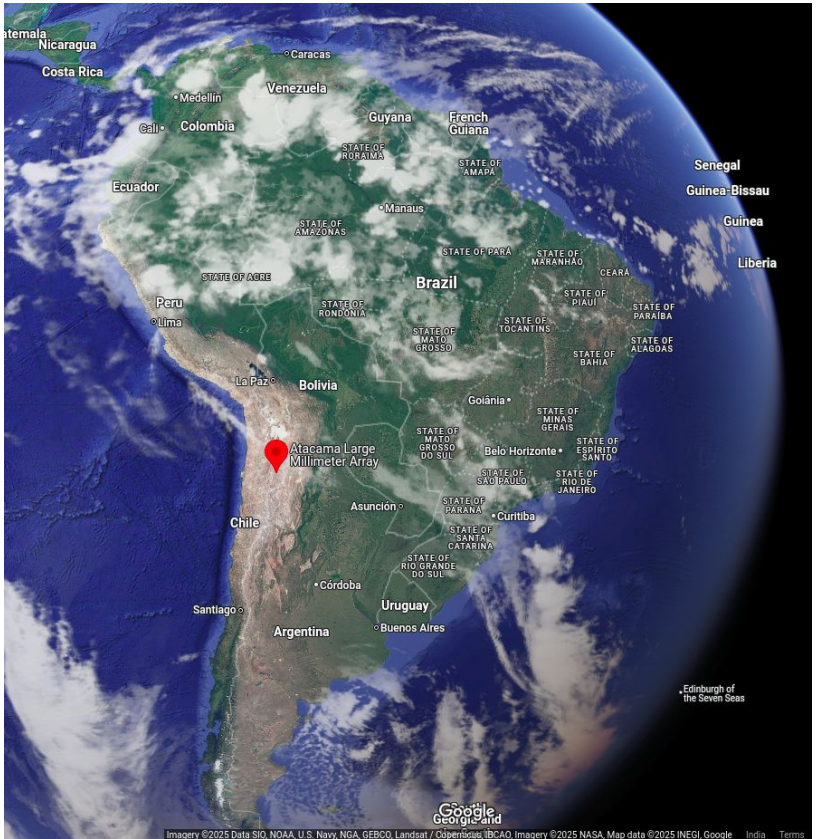
- 197 antennas
- 350 MHz - 15.4 GHz (24 GHz)
- 150 km footprint
- Construction underway
- Science operations - 2029
- Huge improvement in sensitivity and imaging quality



MeerKAT Telescope - actual photograph

Image credit - SARAO

Atacama Large Millimeter/submillimeter Array (ALMA)

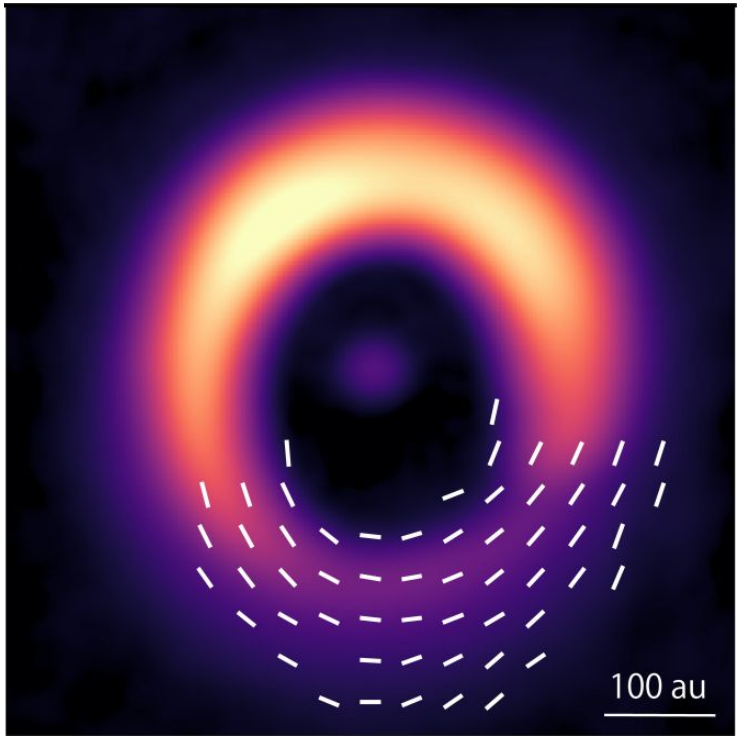


Atacama Large Millimeter/submillimeter Array (ALMA)

- 66 high precision antennas
- 31 - 1000 GHz
- 150 m to 16 km baselines

Image credit - ESO

Atacama Large Millimeter/submillimeter Array (ALMA)



Cosmology and the high redshift universe, Galaxies and galactic nuclei, ISM, star formation and astrochemistry, **Planet-forming disks**, Stellar evolution, Solar system

Protoplanetary disk surrounding HD 142527. The white bars show the measured direction of the magnetic field (~0.3 milliGauss, 1/1000 of Earth's magnetic field at a distance of 519±2 light years).

Credit: ALMA (ESO/ NAOJ/ NRAO)

Agenda Item 1.16

Report **ITU-R RA.[NGSO-RAS-RQZ]**
Mitigation techniques to improve data collection quality at RA in the RQZ

📡 Studies on Coexistence Measures

🌍 Inputs from Key Stakeholders

- Telesat, USA, Canada, SKAO, Korea

🛰️ **Focus Areas**

- New coexistence measures between non-GSO satellite systems & RAS stations in RQZs
- Based on Resolution 681 (WRC-23), Resolves 5
- Enhancing RAS data collection in specific RQZs

🚀 **Coexistence Approaches**

✅ Boresight Avoidance
✅ Temporal Avoidance & Frequency Hopping
✅ Reduced Transmit Power Levels
✅ Null Steering
✅ RAS Observations in Unallocated Bands

Impact Simulations of Coexistence Methods

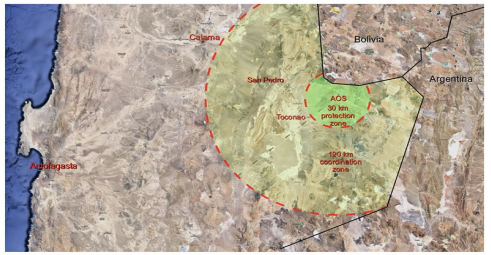
📡 **Based on ITU-R Recommendation SM.1413-4**: Uses Non-GSO system parameters for coexistence studies.

🛰️ **Satellite Position Propagation**: Uses SGP4 model (for orbits < 5,877.5 km), Assumes no atmospheric drag for simplification.

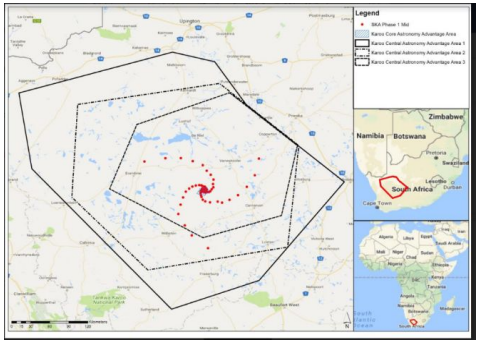
🎯 **Satellite Selection Strategy**: Default selection: Random assignment., Limited by Nco: Max number of non-GSO satellites operating co-frequency.

🔭 **RAS Station Pointing**: Can point anywhere in azimuth & elevation, Uses ITU-R S.1586-1 to generate random sky pointings.

📶 **Radio Wave Propagation**: ITU-R P.525-5 (Free Space Path Loss), ITU-R P.619-5 (<100 GHz), ITU-R P.676-13 (>100 GHz).



ALMA protection and coordination zones



Declared Karoo Core and Karoo Central Astronomy Advantage Areas

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Operational Coexistence Measures:
National RQZ in the US and boresight avoidance technique

🌍 National Radio Quiet Zone (USA) & Boresight Avoidance

- Coordinated testing since Fall 2021 between NRAO & a LEO satellite operator
- Experiments conducted at:
    - Karl G. Jansky Very Large Array (VLA), New Mexico
    - Green Bank Telescope (GBT), West Virginia

🚀 Boresight Avoidance Technique

✅ Adaptive Tasking: Downlink beams placed far from telescope sites

✅ Direct Illumination Avoidance: Satellites avoid main telescope beam

✅ Dynamic Downlink Management:

- Redirect or disable downlinks near boresight
- Defined angular separation thresholds (e.g., 2° from boresight → beams 180 km away)
- Tighter cone → completely disable satellite beam

📊 Key Experimental Findings (2023-24)

1. Satellite systems can disable downlink beams when informed of telescope pointing & frequency
2. Boresight avoidance significantly reduces interference: SNR reduced by 2 orders of magnitude inside 0.5° radius
3. Adjacent RAS band leakage mitigation:
    - Initial 3x signal increase in Experiment #1 with $\Delta\theta bs \leq 0.5°$
    - No issue when boresight avoidance is applied

🔬 Impact & Future Prospects

✅ Ensures coexistence of radio astronomy & commercial satellites

✅ Expands radio telescope observations without harmful interference

✅ Enhances satellite communication services while protecting scientific research

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to consider, based on the results of ITU Radiocommunication Sector studies, possible regulatory measures regarding the **protection of the Earth exploration-satellite service** (passive) and the **radio astronomy service** in certain frequency bands **above 76 GHz** from **unwanted emissions of active services**, in accordance with Resolution 712 (WRC-23);

Resolves 2 **compatibility studies** between the RAS and the active satellite services in certain **adjacent and nearby frequency bands** listed in Table 2 below with a view to setting the **relevant threshold levels** for unwanted emissions from any GSO and non-GSO space stations and revising and updating Resolution 739 (Rev.WRC-19) accordingly:

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TABLE 2

RAS frequency bands to be studied and corresponding active services to be included

Radio astronomy frequency band	Active satellite service frequency band	Active satellite service (space-to-Earth)
76-81 GHz	71-76 GHz	Fixed-satellite service (FSS), mobile-satellite service (MSS), broadcasting-satellite service (BSS)
130-134 GHz	123-130 GHz	FSS, MSS, radionavigation-satellite service (RNSS)
164-167 GHz	167-174.5 GHz	FSS
226-231.5 GHz	232-235 GHz	FSS

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Focus Areas

1. **Developing a working document on compatibility between the Radio Astronomy Service (RAS) and active satellite services in the 71-235 GHz range (ITU-R RA.[NGSO-RAS-RQZ])**
    a. Recommendation ITU-R RA.769-2 defining methods for calculating threshold interference levels in radio astronomy
        i. parameters like integration time, frequency, bandwidth, and system temperature
    b. Recommendation ITU-R RA.1513-2 sets interference feasibility criteria:
        i. 5% maximum data loss from all interferers 2% data loss limit from a single system exceeding RA.769-2 limits
    c. **No Agreement Reached**
        i. On epfd values and methodology for specific frequencies above 76 GHz in Rec. ITU-R RA.769-2
2. **Advancing the working document PDNRec ITU-R RA.1631**
    a. Scope addition to the Recommendation (reference antenna pattern based on the epfd concept for frequencies up to 275 GHz)
    b. Updated table of typical maximum RAS antenna gain extending frequency range from 43.5 GHz to 275 GHz
3. **Formulating an initial proposal for updating Resolution 739 as per Resolution 712** (compatibility between RAS and active space services in certain adjacent and nearby frequency bands)
4. **Drafting a reply liaison statement to WP 4A -** seeking clarification on FSS system characteristics provided by W 4A
5. **Progress on ten key documents, addressing various aspects of radio astronomy, lunar-based facilities, and interference mitigation.**

LS to 4C

Status of Indian Contribution Document (7D/173) – WRC-27 Agenda Item 1.13

📌 **India's Proposal: Inclusion of GMRT**

✔ India proposed the Giant Metrewave Radio Telescope (GMRT), located in Pune, Maharashtra, as a representative radio astronomy site for studies under WRC-27 Agenda Item 1.13, to be reflected in a reply Liaison Statement (LS) to WP 4C.

❗ **Meeting Outcome**

✔ The meeting did not agree to send a further reply LS to WP 4C regarding GMRT

✔ It was suggested that if India is interested in including GMRT in the studies, it may:

📤 Submit a dedicated study to WP 4C independently.

Observatory name, place, administration	Longitude (E) Latitude (N) Elevation (m AMSL)	Minimum elevation (degrees)	Rx height above terrain (m)	URL Geographical characteristics
Giant Metrewave Radio Telescope, **30 x 45m antenna,** **Pune, Maharashtra, India**	19º 05' 26.32" 74º 02' 59.65" 642 to 690 m	15	43.5	https://www.gmrt.ncra.tifr.res.in/, Broad plains with some hills towards the periphery

Reply LS to WP 4A

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🛰️ WP 7D requests further details/ clarification:

- ✅ Gateway Station Deployment Density
- ✅ Justification for Power Flux-Density (pfd) Values for System A
- ✅ Confirmation that pfd values apply to a single satellite
- ✅ Modeling Approach for Out-of-Band Emissions
- ✅ Clarification on “Random” Pointing Strategy
- ✅ Guidance on Aggregate Interference Levels from multiple non-GSO FSS systems at RAS sites

📍 **Coordination & Protection Zones:**

- Do not apply to space stations
- These zones are national issues & not considered under WRC-27 Agenda Item 1.16

📡 **Observations in Non-RAS Allocated Bands (RR 4.4):** Measurements at two RQZs listed in considering k) of Resolution 681 are

- Based on WRC-23 conditions
- Under the full responsibility of the notifying administration of the RAS observatory sites

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🛰️ WP 7D seeks further clarification regarding the FSS system characteristics provided for compatibility studies:

- ✅ System Characteristics
  - Whether the provided characteristics pertain to user terminals or gateways
  - Whether they refer to uplink or downlink operations
  - Confirmation that the provided pfd values apply to a single satellite
- ✅ Additional Parameters for ITU-R S.1528
  - WP 7D inquires whether additional parameters are needed for applying ITU-R S.1528 in studies under Agenda Item 1.18
  - Requests WP 4A to provide these parameters if required
- ✅ Out-of-Band Emission Mask Modeling
  - WP 7D seeks guidance on the appropriate modeling approach
  - Considering ITU-R SM.1541-6, which differentiates between single-carrier and multi-carrier systems

Additional Indian Context

Efforts underway for setting up antennas the site of the Giant Metrewave Radio Telescope for VLBI science with partners from Asia, Australia and Europe.

- Planned operations spanning 1.4 GHz - 20 GHz
- Effort being initiated for inclusion in Master Frequency Allocation Register (MFAI)

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Report ITU-R [**RAS-SAT 71-235 GHZ**]

📌 **Threshold Interference Calculations**

✔ Recommendation ITU-R RA.769-2 defining methods for calculating threshold interference levels in radio astronomy

- parameters like integration time, frequency, bandwidth, and system temperature

✔ Recommendation ITU-R RA.1513-2 sets interference feasibility criteria:

- 5% maximum data loss from all interferers 2% data loss limit from a single system exceeding RA.769-2 limits

🚫 **No Agreement Reached**

- On epfd values and methodology for specific frequencies above 76 GHz in Rec. ITU-R RA.769-2

ITU-R **RA.1631** on RAS Antenna Patterns

📌 **Preliminary draft revision of ITU-R RA.1631 introduces**

- Scope addition to the Recommendation (reference antenna pattern based on the epfd concept for frequencies up to 275 GHz)
- Updated table of typical maximum RAS antenna gain extending frequency range from 43.5 GHz to 275 GHz

AI 1.16 - Actions to be taken

- Studies on how the interference from unwanted emissions from a single and aggregate non-GSO satellite system operating in the adjacent and nearby frequency bands in Table 1 affects the operation of RAS stations in frequency bands allocated to the RAS on a primary basis in Table 1;
- Studies on the possible recognition of the specified RQZs (resolves 3)
- Studies on how the aggregate interference from single and multiple non-GSO satellite systems affects the operation of RAS stations in the specified RQZs
- Studies on new coexistence measures between non-GSO satellite systems and RAS stations in the specified RQZs
- Studies of methods to calculate the necessary separation distances between gateways of non-GSO systems operating in bands adjacent to or near RAS allocations and RAS stations protected by the specified RQZs

AI 1.16 - Outcomes (Sub working group 7D-1)

- Defining the scope of the AI and refining procedures for producing the CPM text.
- Sent a liaison statement to WP 4A, seeking clarification on specific points related to Resolves 3-6 of Resolution 681 (WRC-23) and reaffirming its understanding of the intended outcomes.
- Progressed on a new document, PDNRep ITU-R RA. [RAS-NGSO], which has a broader scope than AI 1.16.
- Elements document on Resolves 3/IRQZ was created
- Elements document addressing the epfd methodology was created.
- Progress was made on PDNRec RA.[NGSO-RAS-RQZ], incorporating modifications and an editor's note clarifying that the document serves as informational.