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Spectrum Issues (NSF)

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Presentation to CORF

May 18, 2010

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Spectrum Has Become a National Priority

- FCC Releases National Broad Band Plan (3/15/10)
- Spectrum Inventory Bills introduced in the House and the Senate
- HR 3125 (passed April 14, 2010; 319yes/18no)
  - > Requires NTIA and FCC to inventory spectrum uses between 225 MHz and 3.7GHz / up to 10 GHz
  - > Submit periodic reports to Congress, including what spectrum should be relocated…
  - > Make Results Available to the Public through the Internet..
- S. 649, pending, requires spectrum inventory, biennially, in the 300 MHz to 3.5 GHz range, similar requirements to HR 3125

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The FCC's Broad Band Plan

- Lists 6 Goals
- Goal 2: *The United States should lead the world in mobile innovation, with the fastest and most extensive wireless networks of any nation.*
- Action: "Make 500 megahertz of spectrum newly available for broadband within 10 years "
- Details: http://www.broadband.gov/plan/

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The FCC's Broadband Plan

"Broadband is the great infrastructure challenge of the early 21st century".

"Like electricity a century ago, broadband is a foundation for economic growth, job creation, global competitiveness and a better way of life. It is enabling entire new industries and unlocking vast new possibilities for existing ones. It is changing how we educate children, deliver health care, manage energy, ensure public safety, engage government, and access, organize and disseminate knowledge."

"Spectrum is a major input for providers of broadband service. Currently, the FCC has only 50 megahertz in inventory, just a fraction of the amount that will be necessary to match growing demand. More efficient allocation and assignment of spectrum will reduce deployment costs, drive investment and benefit consumers through better performance and lower prices"

Executive Summary

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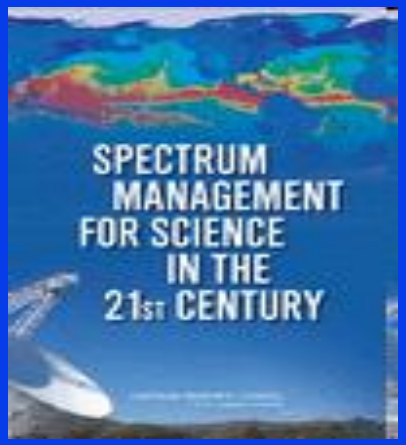
Spectrum Management for Science (SMS)

- Spectrum Management for Science in the 21st Century, NRC Report, Released in December, 2009
- Supported by NSF, NASA, NOAA, NTIA
- Extensive Set of Recommendations Directed at Funding Agencies, FCC, NTIA



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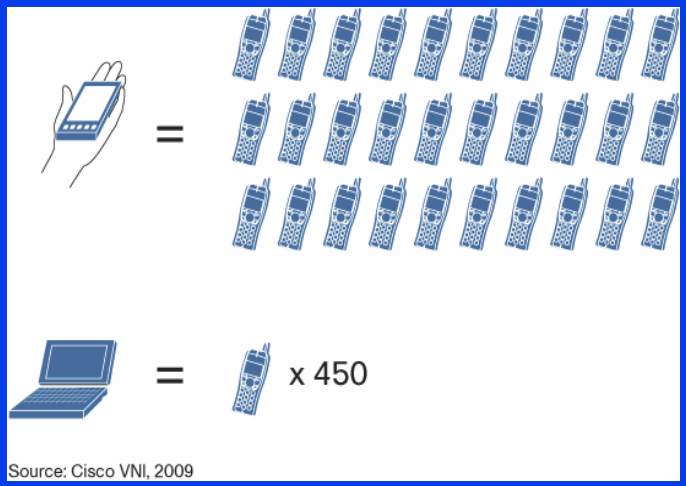
Trends

Commercial:

Wireless Applications in Many Portions of the Spectrum, Particularly Below 5 GHz

In Terms of Bandwidth:



Radio Astronomy:

Not confined to Allocated Bands, Full Spectrum Coverage is demanded by Science

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Frequency Allocation Challenge

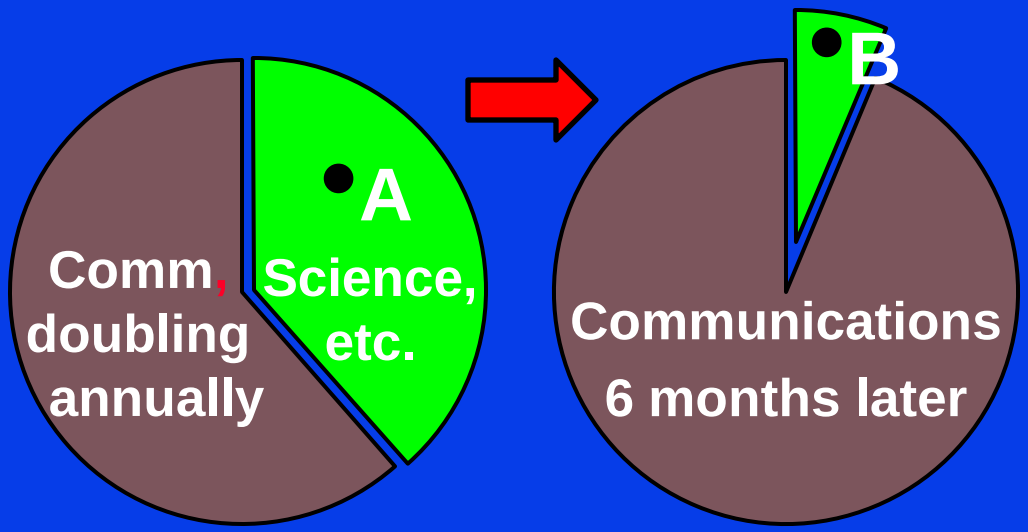
Science utilization: Roughly proportional to number of scientists, ~ steady

Communications: Exponential growth

Consider a spectral region where communications double annually

If communications occupies 2/3 and other users yield to communications, others would shrink from "A" to "B"

Yielding buys only six months before communications becomes 100%; science uses might represent only one month of growth.



Conversely, if Science doubled, communications capacity would again shift only ~one month

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The Path Forward

- **Dynamic Spectrum Assignment – Cooperative Spectrum Usage – Cognitive Radio**
  - > **Technologies are coming into being, but standards and protocols (regulation) do not exist (yet!)**
  - > **Regulations when they exist, (or future) are considered NATIONAL regulatory issues – not very helpful to passive services (and often, not even to active services)**
- **Mitigation**
  - > **See Rec. 6 of SMS – Investment in the development of mitigation technology should be increased…NSF and NASA should support R&D for unilateral RFI mitigation technology….**

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However…

- No universal mitigation technology, applicable to all situations…
- Mitigation techniques can't be applied to low level RFI (< 3σ rms noise)

MOREOVER

Mitigation techniques should be tested and used!!!!

- RFI2010 Workshop: Most RFI elimination is (still) done by hand (flagging), however
- With the extremely high data rates of new telescopes coming on line such methods will no longer be viable, and automatic methods will have to be developed!

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Radio astronomy involvement in spectrum management activities (international)

• **Americas:**		
US	**4**	**3**
Canada	**1**	**0**
• **Europe**	**1**	**1**
Netherlands	**1**	**1**
Germany	**1**	**1**
France	**1**	**1**
U.K.	**1**	**1**
Russia	**1**	**0**

• **Asia**		
Japan	**1**	
India	**1**	**0**
Korea	**1**	
China		
• **Australia**	**1**	

Total: ~ 12

down worldwide since 2003 (15)

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WRC-12

- Next WRC to be held in Geneva, Jan 23-Feb 17, 2012
- Agenda adopted at WRC-07;
  ~ 30 items,
  ~ 15 have varying degrees of relevance to radio astronomy
- Preceded by the Conference Preparatory Meeting (CPM) 14 -25 Feb, 2011
- CPM text needs to be finalized at current series of meetings (WP 7D – June 14-18)

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The main course (for radio astronomy)

1.6 to review No. **5.565** of the Radio Regulations in order to update the spectrum use by the passive services between 275 GHz and 3 000 GHz, in accordance with Resolution **950 (Rev.WRC-07)**, and to consider possible procedures for free-space optical-links, taking into account the results of ITU-R studies, in accordance with Resolution **955 (WRC-07)**;

AI 1.6

- **Res. 950 - Revision of footnote 5.565, based on ITU-R studies**
  - > **Revise the listing of bands in the 275 - 1000 GHz range, currently in the footnote**
  - > **Extend the range of the footnote, to cover up to 3000 GHz**
- **Res. 955 - Consider possible procedures for free-space Optical Links, based on ITU-R studies**

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Footnote 5.565 (Current)

- The frequency band 275 – 1000 GHz may be used by administrations for experimentation with, and development of, various active and passive services. In this band a need has been identified for the following spectral line measurements for passive services:
  - Radio astronomy service: 275-323 GHz, 327-371 GHz, 388-424 GHz, 426- 442 GHz, 453-510 GHz, 623-711 GHz, 795-909 GHz and 926-945 GHz;
  - Earth exploration-satellite service (passive) and space research service (passive): 275-277 GHz, 294-306 GHz, 316-334 GHz, 342-349 GHz, 363-365 GHz, 371-389 GHz, 416-434 GHz, 442-444 GHz, 496-506 GHz, 546-568 GHz, 624-629 GHz, 634-654 GHz, 659-661 GHz, 684-692 GHz, 730-732 GHz, 851-853 GHz and 951-956 GHz.
- Future research in this largely unexplored spectral region may yield additional spectral lines and continuum bands of interest to the passive services. Administrations are urged to take all practicable steps to protect these passive services from harmful interference until the date when the allocation Table is established in the above-mentioned frequency band.

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AI 1.6 – Options

- Modify RR 5.565, eliminating the list of bands and simply refer to Resolutions addressing the use of 275-3000 GHz by radio astronomy and remote sensing (separate resolutions)
- Maintain 5.565, with appropriate modifications in the range currently covered. Refer use of 1000-3000 GHz to Resolutions, very likely claiming that the passive services are interested in use of the full 1-3 THz range, and that this can be done without constraints on the active services (using the same range), because of:
  - Extremely high absorption
  - Very small beam sizes / probability of beam coupling
  - Low power generation capabilities (at least at present) in the THz region
- Several possibilities to deal with Res 955, amounting to NOC in the RR

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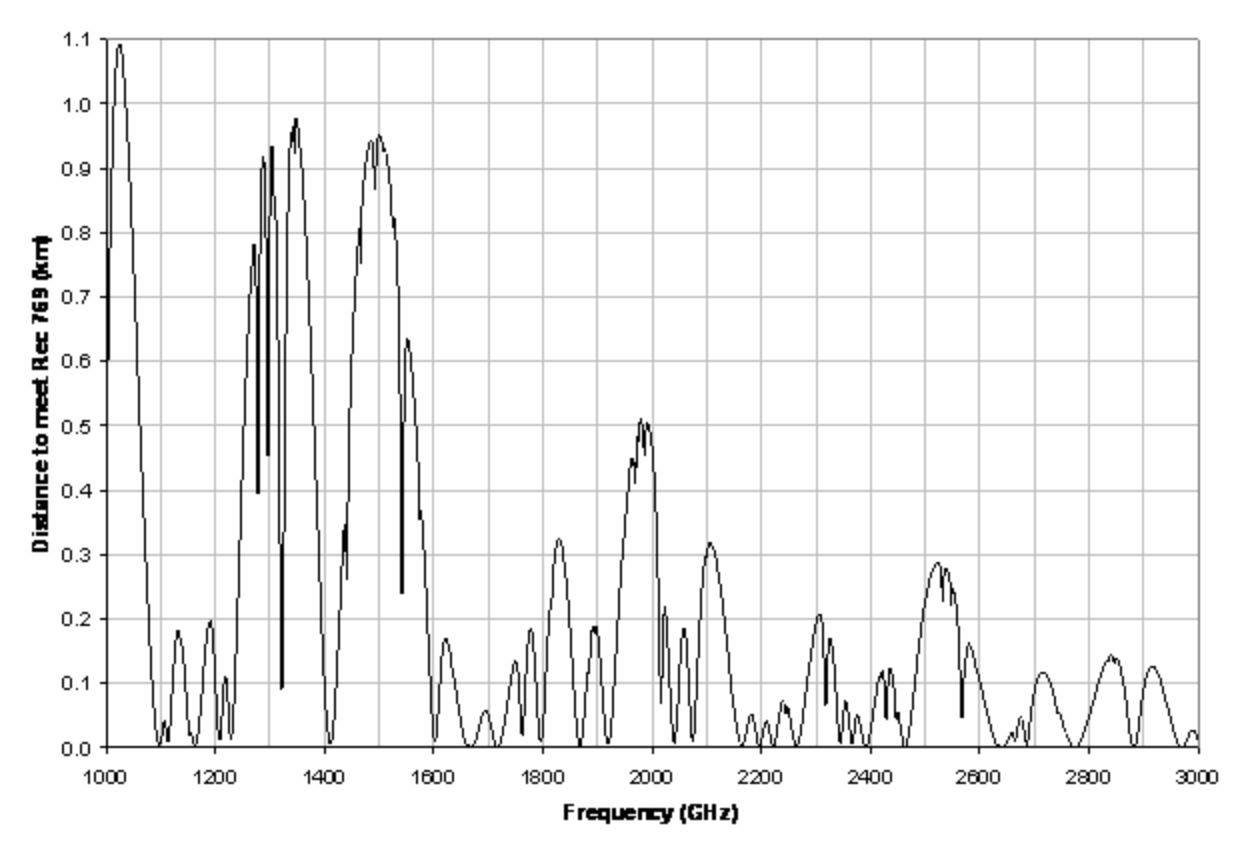
Distance at which Rec. ITU-R RA.769 is met, under near worst case assumptions

(see A. Clegg - US WP7D/71)



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Other WRC-12 Agenda Items
Band Specific (1)
AIs That May Impact the 4990-5000 MHz Band

- **AI 1.4. "….to consider, …. further regulatory measures to facilitate introduction of new aeronautical mobile (R) service (AM(R)S) systems in the bands …5 000-5 030 MHz"**
  - **Issue: airborne transmitters operating next to the widely used primary 4990-5000 MHz radio astronomy band**
    - ***Allocation to be used by surface LAN's at airports only, using very low power levels***
    - ***As per a Resolution, coordination would be required with radio astronomy observatories within 150 km of airports using the allocation (e.g. Arecibo, Jodrell Bank)***
- **AI 1.18"… extending the existing …radiodetermination-satellite service (space-to-Earth) allocations in the band 2 483.5-2 500 MHz in order to make a global primary allocation, and determine the necessary regulatory provisions…."**
  - **Issue: 2nd harmonic of downlink falls on 4990-5000 MHz RA band, currently subject to footnote RR 5.402, that urges protection of RA**
    - ***Terms of RR 5.402 should be maintained (or strengthened) if a worldwide primary allocation is made to the RDSS***

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Other WRC-12 Agenda Items Band Specific (2)

- **AI 1.5 "to consider worldwide/regional harmonization of spectrum for electronic news gathering (ENG).."**

- **AI 1.13 " to ….decide on the spectrum usage of the 21.4-22 GHz band for the broadcasting-satellite service and the associated feeder-link bands in Regions 1 and 3"**
  - **Issue: Possible unwanted emissions from strong DTV Satellite Broadcasting signals into the 22.21-22.5 GHz primary radio astronomy band**
    - **The band pair 21.4-22 GHz/22.21-22.5 GHz is included in Table 1 of Res. 739 (WRC-07). Assuming a maximum pfd level of -105 d(BW/m^2) at the Earth's surface, filtering of BSS emissions to the Rec. ITU-R RA.769 level should be possible**

- **AI 1.21. "to consider a primary allocation to the radiolocation service in the band 15.4-15.7 GHz…"**
  - **Issue: Strong, possibly airborne transmitters operating next to the 15.35-15.4 GHz passive band**
    - **Regulatory measures (footnote) should limit unwanted emissions into the passive band. US draft proposal*: 5.YYY In order to protect the radio astronomy service in the band 15.35-15.4 GHz, radiolocation stations operating in the 15.4-15.7 GHz band shall not exceed the level of –156 dB(W/m^2) in a 50 MHz bandwidth, at any radio astronomy observatory site for more than 2% of the time.***

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Other WRC-12 Agenda Items
Band Specific (3)

- **AI 1.15 " to consider possible allocations in the range 3-50 MHz to the radiolocation service for oceanographic radar applications.."**
  - **Issue: potential for interference into 13.6 MHz, 26 MHz and/or 38 MHz radio astronomy bands. Impact on LWA, MWA, SKA…**
- **AI 1.20 "spectrum identification for gateway links for high altitude platform stations (HAPS) in the range 5 850-7 075 MHz in order to support operations in the fixed and mobile services"**
  - **Issue: Potential interference with observations of the 6650-6675.2 MHz band, identified for observations of the 6668 MHz methanol line**
    - **RR 5.149 All practicable steps, only..**
    - **WP 7D Liaison statement to WP 5C (Liszt) , noting astronomers interest in the 6650-6675.2 MHz band and requesting HAPS downlink to be located as far above 6675.2 MHz, as possible.**

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Broad Issues (1) – AIs likely to result in NOC

- **AI 1.2 "Taking into account ITU-R studies ….to take appropriate action with a view to enhancing the international regulatory framework"**
  - **Revise Service definitions, consider the possibility of merging some services**
  - **Unlikely to affect RA – However it needs to be monitored as FSS and MSS may be merged on a band-by-band basis**
- **AI 1.19 to consider regulatory measures and their relevance, in order to enable the introduction of software-defined radio and cognitive radio systems**
  - **US: There appears to be no inclination to changes**
- **AI 1.22 "…examine the effect of emissions from short-range devices on radiocommunication services….."**
  - **Code for "Is International Regulation of Short Range Devices (e.g. RFID) Necessary?"**

    US favors (minimal) national regulations only

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Broad Issues (2)

- AI 1.8 " to consider the progress of ITU-R studies concerning the technical and regulatory issues relative to the fixed service in the bands between 71 GHz and 238 GHz…"
  - France (Doc 5C/178): Issue is national, no international regulation is needed
  - Work to be performed in WP 5C – Concern due to recent revision of Report F.2107 that mentions 110-130 GHz band as candidate for last mile FWA
- AI 1.3 "…to consider spectrum requirements and possible regulatory actions, including allocations, in order to support the safe operation of unmanned aircraft systems (UAS)…"
  - US: Use current AM(R)S, AMS(R)S, ARNS bands, new allocations only if those prove to be insufficient for the requirements...

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Broad Issues (3)

- AI 1.7 “to ensure long-term spectrum availability and …to meet requirements for the aeronautical mobile-satellite (R) service, and to take appropriate action on this subject, while retaining unchanged the generic allocation to the mobile-satellite service in the bands 1 525-1 559 MHz and 1 626.5-1 660.5 MHz”

- AI 1.14 consider requirements for new applications in the radiolocation service and review allocations or regulatory provisions for implementation of the radiolocation service in the range 30-300 MHz,
- AI 1.25 to consider possible additional allocations to the mobile-satellite service

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Future Issues

- **AI 8.2 "to recommend ….items for inclusion in the agenda for the next WRC" - (possibly 2015)**
  - > **Are There any Astronomy/Science Related Requirements? Allocation or Regulatory? (protection of the SKA?)**
    - **If there is, it's not too soon to start working on placing it on the Agenda.**
- **AI 1.6b "to consider possible procedures for free-space optical-links, taking into account the results of ITU-R studies"**
  - ➢ **Regulation (registration) of optical links on the current Agenda could be deleted, but**
  - ➢ **As optical links are used more and more, some minimal regulation could eventually come into being in the future**

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WP 7D

- SG 7 (Science Services)
  - WP 7A (Time and Frequency Standards)
  - WP 7B (Space Radiocommunication Systems)
  - WP 7C (Remote Sensing Systems)
  - WP 7D (Radio Astronomy)
- WP 7D Chair: Tasso Tzoumis, Australia (CSIRO, ATNF)
- If you want to participate in WP 7D activities please e-mail: tgergely@nsf.gov or aclegg@nsf.gov

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WP 7D Activity

- **Recommendations:**
  - **Preferred Frequency Bands for Radio Astronomy in the 1-3 THz Range (A. Clegg) – New -approved**
  - **Rec. ITU-R RA.1237 Protection of the Radio Astronomy Service from Unwanted Emissions Resulting from the Applications of Wideband Modulation – (T. Gergely) Revision – approved**
  - **Rec. ITU-R RA.1513 Levels of Data Loss to Radio Astronomy Observations and Percentage-of-Time Criteria Resulting from Degradation by Interference for Frequency Bands Allocated to the Radio Astronomy Service on a Primary Basis – Revision (Europe)**

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WP 7D Activity

- **Reports (New)**
  - **Radio Quiet Zones – C. Wilson (Australia)**
    Intended to be mostly descriptive of what exists and common characteristics.
  - **DTV transition – A. Clegg**
    Impact on Radio Astronomy and State/Regulation of DTV in various countries
  - **Astronomical Use of Frequency Bands 50-300 THz – K. Tapping (Canada) - approved**
  - **Description of astronomical observations, anticipating that the ITU will play some role in this frequency range**
  - **Essential Role of Observations – Ch van Diepenbeek (The Netherlands)**
    Importance of observations for passive services, investment in them and the benefits they offer to society
- **Revision/update needed: Mitigation Methods in Radio Astronomy (S. Ellingson/M. Lewis)**

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CubeSats

- **CubeSats :**
  - **“miniaturized satellite for space research that has a volume of exactly one liter (10 cm cube), weighs no more than one kilogram, and typically uses commercial off-the-shelf electronics components”.**
  - **Cost ~ $ 100K ; Can piggyback on launches, or launch many at one launch.**
- **NSF program to use CubeSats for science missions, dedicated to space weather and atmospheric research**
- **First deadline for proposals: May, 2008; annually in February, thereafter (3-6 awards) .**
- **Problem: No specific band designated for data transmissions**
- **CubeSats have been using the amateur bands for data transmission, but this cannot be done indefinitely**
- **Spectrum will be needed for CubeSats (Micro Sats) - A Question will/should be introduced (WP 7B) to explore the options and conduct studies**

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Third Summer School in Spectrum Management for Radio Astronomy

Held at the National Astronomical Observatory of Japan, Mitaka, Tokyo, Japan

31 May - 4 June, 2010

For further details, see:

http://www.iucaf.org/SSS2010/

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Back Up Slides

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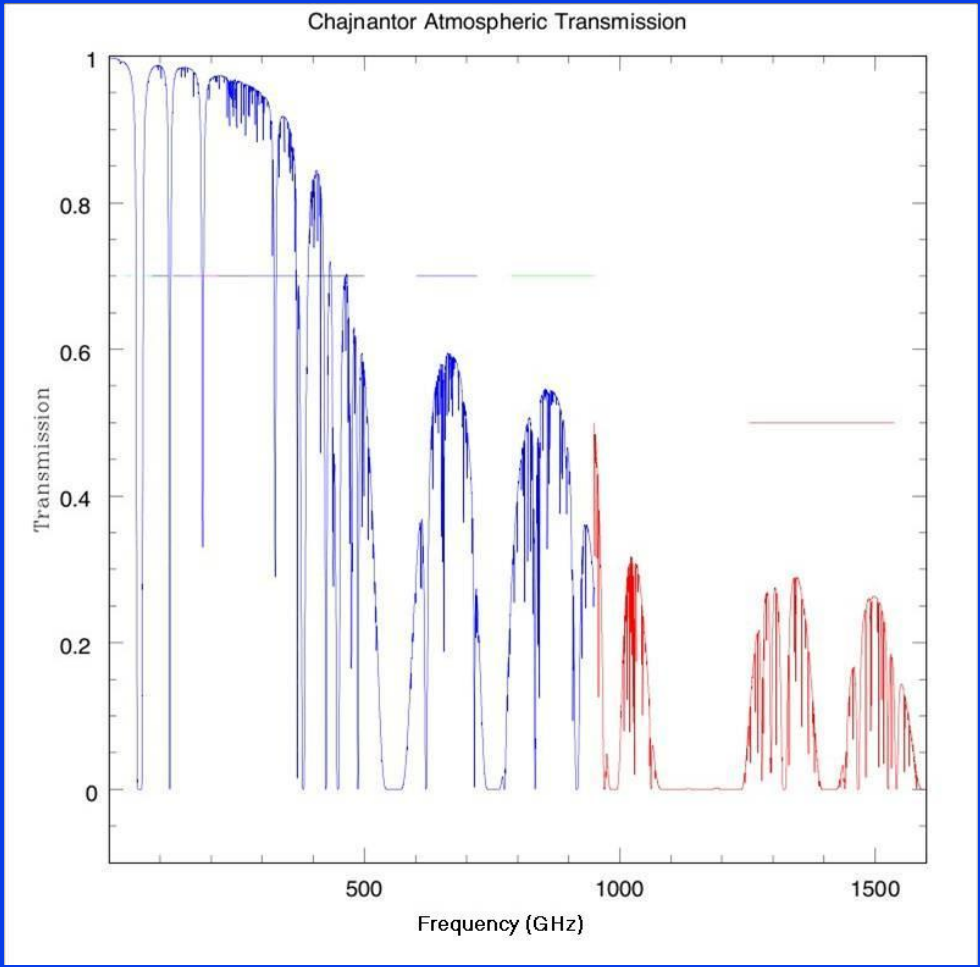
Atmospheric transmission at the ALMA site



Atmospheric transmission at Cerro Chajnantor, at approximately 5000 m altitude.

0.5mm PWV v<950 GHz
0.2mm PWV v>950 GHz

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Probability that a random source of emission falls within the main beam of an antenna ($\Omega/4\pi$), and the probability that two identical antennas happen to be pointed directly within each other's beams, $P_{3D} = (\Omega/4\pi)^2$, as a function of frequency and antenna diameter. The gain of the antenna, $G = 10\log(4\pi/\Omega)$, is also listed.

Frequency (GHz)	Antenna Diameter (cm)	G (dB_i)	$\Omega/4\pi$	Probability of Main Beam Coupling (P_{3D})
1 000	5	54	4×10^{-6}	2×10^{-11}
1 000	10	60	1×10^{-6}	1×10^{-12}
1 000	30	70	1×10^{-7}	1×10^{-14}
2 000	5	60	1×10^{-6}	1×10^{-12}
2 000	10	66	3×10^{-7}	6×10^{-14}
2 000	30	76	3×10^{-8}	8×10^{-16}
3 000	5	64	4×10^{-7}	2×10^{-13}
3 000	10	70	1×10^{-7}	1×10^{-14}
3 000	30	79	1×10^{-8}	2×10^{-16}

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Maximum RF power level that can be generated (currently) between

1 – 3 THz :

$$P = 0.01(1000 - f_{GHz}) \text{ dBm}$$

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Spectral Lines of Astrophysical Interest in the Range 275 – 1,000 GHz

- Working Party 7D (Radio Astronomy) of the ITU has developed a recommendation on spectral lines of astrophysical interest up to 1,000 GHz (Rec. ITU-R RA.314-10)
- This list of lines is considered relatively stable and vetted by the astronomical community, although feedback is always welcome
- Based upon the work of the IAU Division X's Working Group on Astrophysically Important Spectral Lines
- The Recommendation was updated following the IAU GA, August 2009, Rio de Janeiro