The spectrum landscape: prospects for earthly radio astronomy

Harvey Liszt (NRAO & IUCAF)

Radio, optical spectrum pollution treated differently

- Light pollution
  - Byproduct of biologic dependence on broadband optical noise
  - Mistaken as a sign of progress
  - Regulated locally (some exceptions) though influenced globally

- Radio spectrum pollution (aka RFI, "harmful interference")
  - Radio waves are not comparable necessities despite the advertising
  - Immediately causes chaos and dysfunction, to be prevented
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  - Radio spectrum finely divided, not all/nothing like reflected sunlight
  - Highly organized radio astronomy response since 1958-1960
    - "Spectrum management"
    - **https://tinyurl.com/sygkq7c** , **https://tinyurl.com/yxyheela**

5th International IUCAF Spectrum Management School for Radio Astronomy
Stellenbosch, South Africa 2 – 6 March 2020

- Supported by IUCAF, SARAO, RadioNet http://www.iucaf.org/sms2020/
  - No registration or banquet fee!
- Previous schools 2002 (USA), 2005 (Italy), 2010 (Japan), 2014 (Chile)

“RFI is what happens when spectrum management fails”

- Radio scientists also deal directly with received RFI
  - Regular RAS RFI meetings have broadened to incorporate remote sensing, occur more often

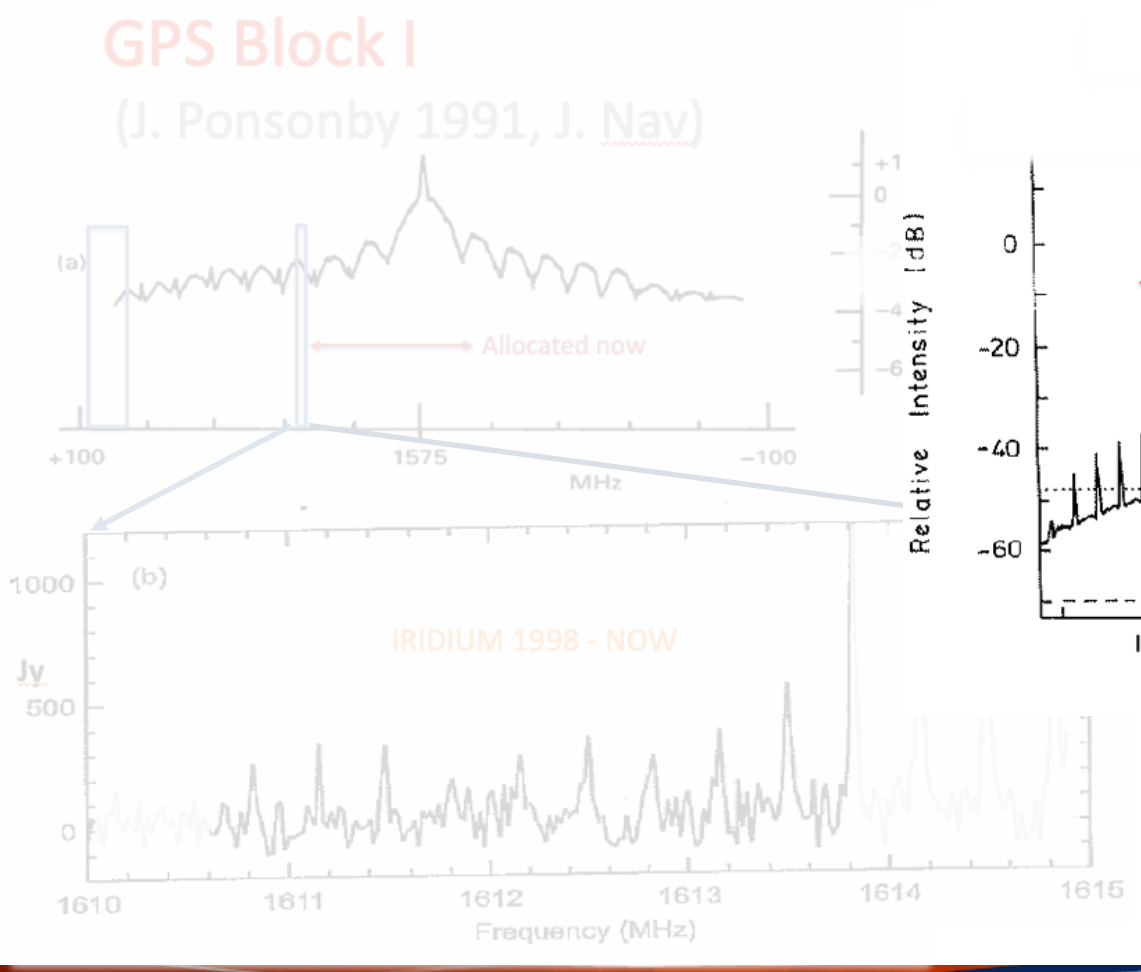
Blue?

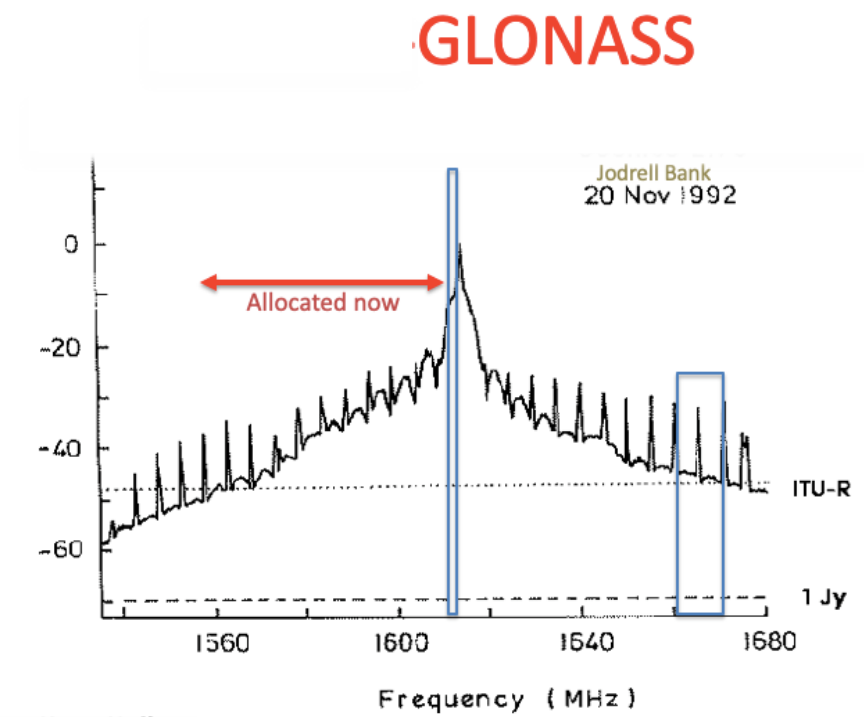
PARTNERS

URSI
CESBIO
cnes
comet
COMmunity of Experts
IEEE
ASTRON
CSIRO
esa
GRSS
NASA
NRAO

RAS's Ah-ha moments came long ago with satellites

- GPS and GLONASS 1978 - 2007; Iridium 1998 - present





What is spectrum management?

- Regulation of use of the radio spectrum
  - Every nation has its radio spectrum regulator & frequency table
    - US has NTIA deep inside Dept of Commerce for Federal spectrum
    - FCC independent agency for private/shared use ("Animal Farm")
  - Radio spectrum defined by UN treaty as 0 – 3 000 GHz (l >100m)
    - Allocated only up to 275 GHz
    - US generally lacks rules for spectrum use above 95 GHz
      - Shared mm-wave spectrum that is free now will eventually be noisy
    - Preferred bands for science identified at 275–1 000 GHz
    - Analogous identification for land mobile & fixed service 275-450 GHz

Goals of spectrum management

- Maximal use of spectrum
- Protection of conforming operations in allocated bands
  - Safety of life services are especially privileged
  - Radio astronomy has some particular privileges too
- Harmonization of band use
  - Frequency mobility from software-defined (frequency agile) radio
- Regulatory certainty to protect investment
  - Operators need regulation, agitate for the kind that suits them

Spectrum management works by:

- Classing uses of the radio spectrum into radio services
  - Fixed, fixed-satellite; mobile, mobile-satellite; radiolocation; maritime, maritime; maritime mobile satellite; broadcasting; amateur; …
  - Radio astronomy (RAS); earth-exploration satellite service (EESS); space research service (SRS); time service. ITU-R Study Group 7
- Allocating spectrum to ***services*** (not operators or applications)
  - Giving primary or secondary status within shared bands
- Writing service rules for using allocations
  - In-band, out of band, spurious emissions all controlled
  - More spectrum allocated than used
    - RAS shares many bands with marginally-compatible services
- Making location/frequency assignments to stations of services
  - Coordinating assignments among operators and services

Innovation and accommodation for science

- Passive service bands not shared with active services
  - RR. 5.340 "***All*** emissions are prohibited in the following bands…"
    - US version US246 includes bands below 1 GHz
    - From1960 when RAS was recognized at ITU-R
    - 1-2% of spectrum below 86 GHz, much more above
      - Nothing for RAS 32 - 86 GHz
    - Used most importantly for weather/climate by EESS

1400-1427 MHz,
2690-2700 MHz, e
No. 5.422,
10.68-10.7 GHz, e
No. 5.483,
15.35-15.4 GHz, e
No. 5.511,
23.6-24 GHz,
31.3-31.5 GHz,
31.5-31.8 GHz, in
48.94-49.04 GHz,
50.2-50.4 GHz[2],
52.6-54.25 GHz,
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226-231.5 GHz,
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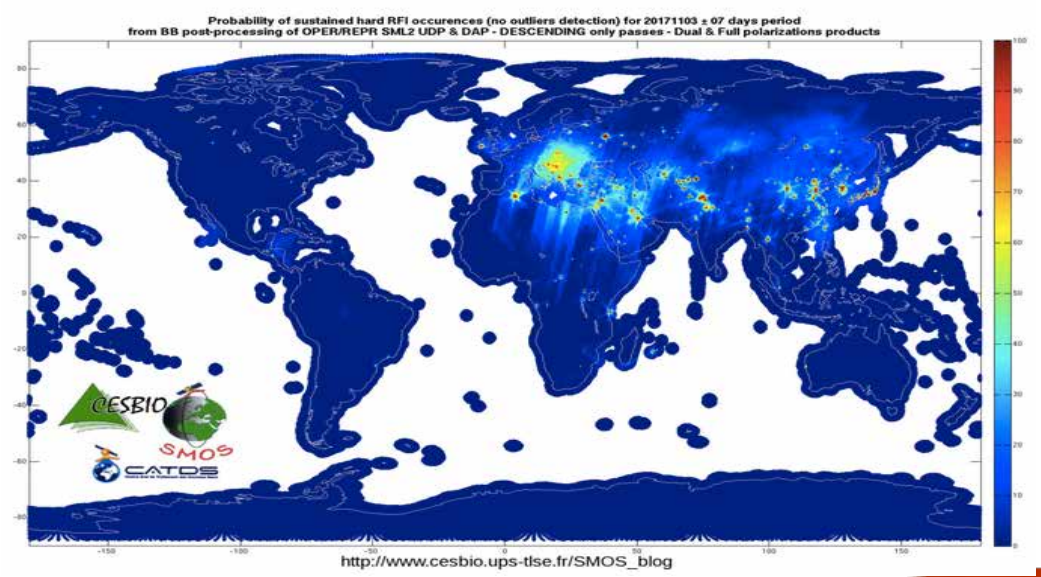

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- Radio quiet zones https://www.itu.int/pub/R-REP-RA.2259-2012
  - US NRQZ was first in1958
    - *Regulates spectrum outside RAS allocations*
  - 15+ RQZ in world now, all operate differently
    - Generally only for fixed terrestrial transmitters
    - SARAO operates the most advanced QZ in Karoo

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ECC Report 271

Table 19: Frequency Bands Used by the SpaceX System

Type of Link and Transmission Direction	Frequency Ranges	RAS band affected
User Downlink Satellite-to-User Terminal	10.7–12.7 GHz	10.6–10.7 GHz (10.68-10.7 passive)
Gateway Downlink Satellite to Gateway	17.8–18.6 GHz 18.8–19.3 GHz	
User Uplink User Terminal to Satellite	14.0–14.5 GHz	14.47–14.5 GHz
Gateway Uplink Gateway to Satellite	27.5–29.1 GHz 29.5–30.0 GHz	
TT&C Downlink	12.15–12.25 GHz 18.55–18.60 GHz	
TT&C Uplink	13.85–14.00 GHz	

SpaceX, OneWeb

- *5G at WRC-15*
  - ***450-470,1427-1452,1492-1518,1710-1885,1885-2025,2110-2200, 2300-2400,2500-2690,3400-3600 MHz***

HAPS

Report ITU-R F.2439-0
(11/2018)

Deployment and technical characteristics of broadband high altitude platform stations in the fixed service in the frequency bands 6 440-6 520 MHz, 21.4-22.0 GHz, 24.25-27.5 GHz, 27.9-28.2 GHz, 31.0-31.3 GHz, 38.0-39.5 GHz, 47.2-47.5 GHz and 47.9-48.2 GHz used in sharing and compatibility studies

WRC-23:

1.2 to consider identification of the frequency bands

- **3 600-3 800 MHz and 3 300-3 400 MHz** (Region 2);
- **3 300-3 400 MHz** (amend footnote in Region 1);
- **7 025-7 125 MHz** (globally);
- **6 425-7 025 MHz** (Region 1);
- **10 000-10 500 MHz** (Region 2),

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  - The scale of new systems is orders of magnitude larger
    - Iridium 75 -> Starlink 1584 -> 4460 -> 12,000 -> 42,000

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  - The passive bands dedicated to science are especially coveted
    - FCC order (ET Docket No. 18-21), experimental licenses for transmission, sale, marketing **in passive bands above 95 GHz**
    - ECC hosting CEPT SE sharing studies in passive bands

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  - **Increasing blurring, mixed use**
    - **Fixed and surface uses will be mobile and airborne**
      - **HIBS - 5G base stations on HAPS (WRC-23 AI 1.4)**
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- Indifferent radio spectrum regulators licensing collateral damage
  - **Orbital debris**
  - **Desecration of the dark night sky**

*"Two things fill the mind ...: **the starry heavens above me and the moral law within me."***

Immanuel Kant, Critique of Practical Reason

The world's radio telescopes / quiet zones

tinyurl.com/yrvszk