Spectrum Management and Radio Astronomy: The Future

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Summary

- Spectrum sharing

U.S. Spectrum Sharing Examples

- TV White Spaces 54~698 MHz (implemented)
  - Broadcasters
  - Sharing
- AWS-1 (implemented; auctioned in 2006)
  - 1710-1755/2110-2155
  - Military & other U.S. government (lots of systems)
  - Some share, most relocation
- AWS-3 (rules adopted; auction later this year)
  - 1695-1710, 1755-1780, and 2155-2180
  - Military & other U.S. government (lots of systems)
  - GOES weather satellite downlinks
  - Some share, some relocation

U.S. Spectrum Sharing Examples

- 5 GHz RLANs (implemented)
  - Radio Local Area Networks (wide-area Wi-Fi)
  - Federal Aviation Administration (FAA) Terminal Doppler Weather Radars (TDWR)
  - Share; RLANS sense & avoid
- 3.5 GHz (under rule making)
  - Small cell networks
  - Military (ship-borne radars on Navy vessels)
  - Share (rules TBD)
- 4200-4400 MHz
  - Worldwide aeronautical radio altimeter
  - Under study for sharing parts with mobile broadband

PCAST Report

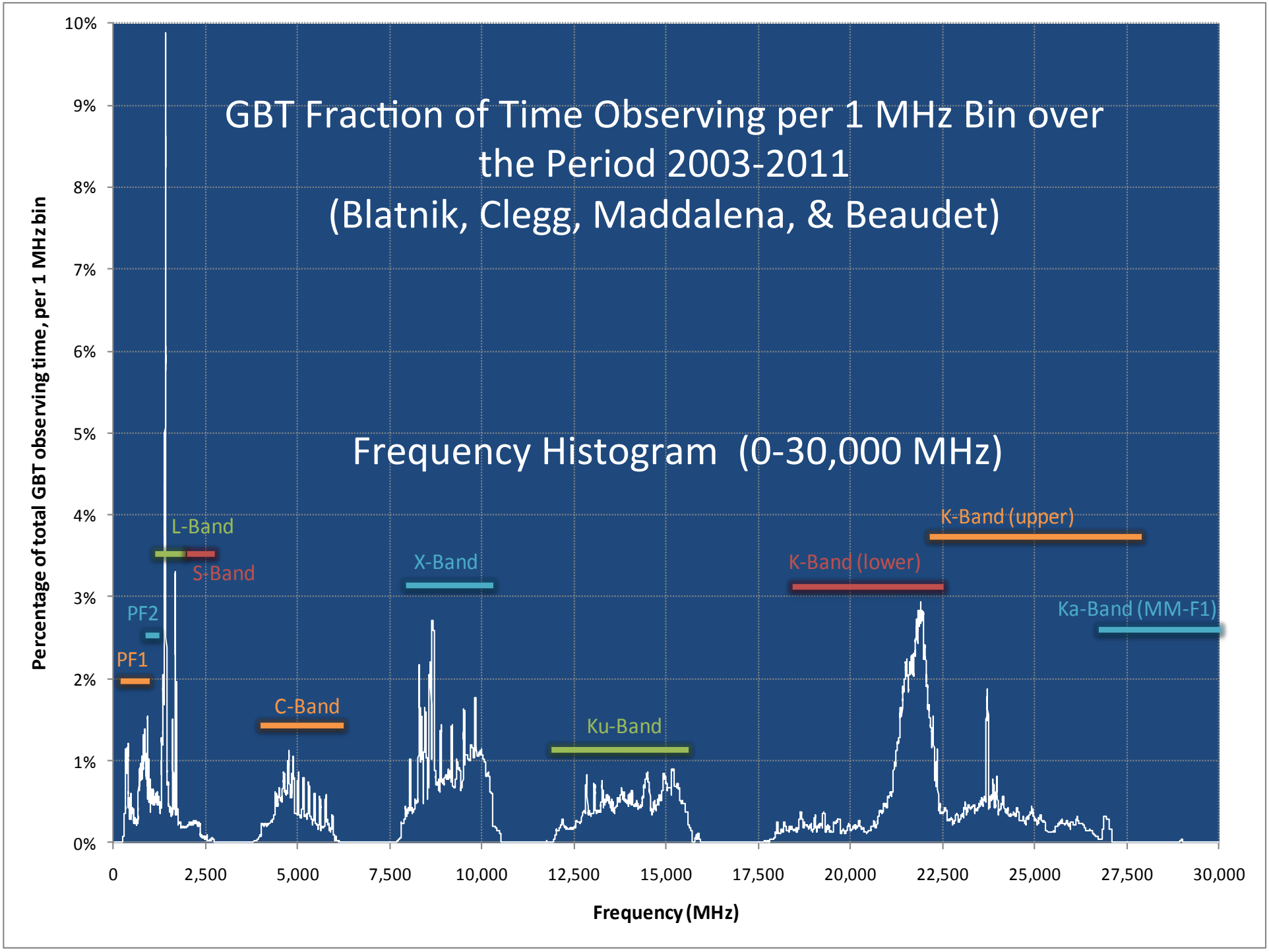
- President's Council of Advisors on Science and Technology
- 2012 report (search for "PCAST spectrum report"):
  - Reallocation and relocation of government spectrum is not sustainable
  - "The essential element of this new Federal spectrum architecture is that the norm for spectrum use should be sharing, not exclusivity"
  - "immediately identify 1,000 MHz of Federal spectrum in which to implement the new architecture and thereby create the first shared-use spectrum superhighways"
  - …

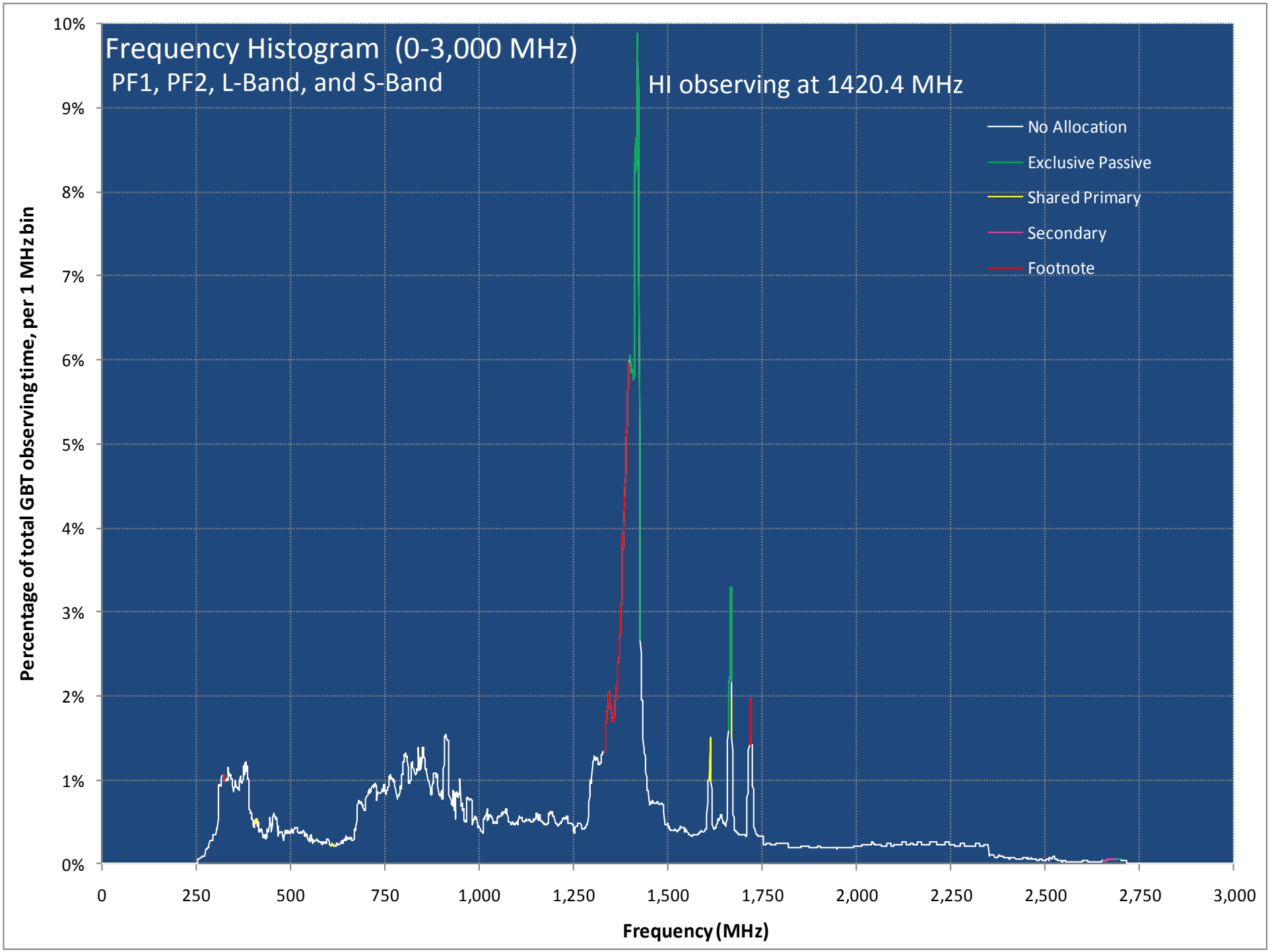
Presidential Memorandum 2013

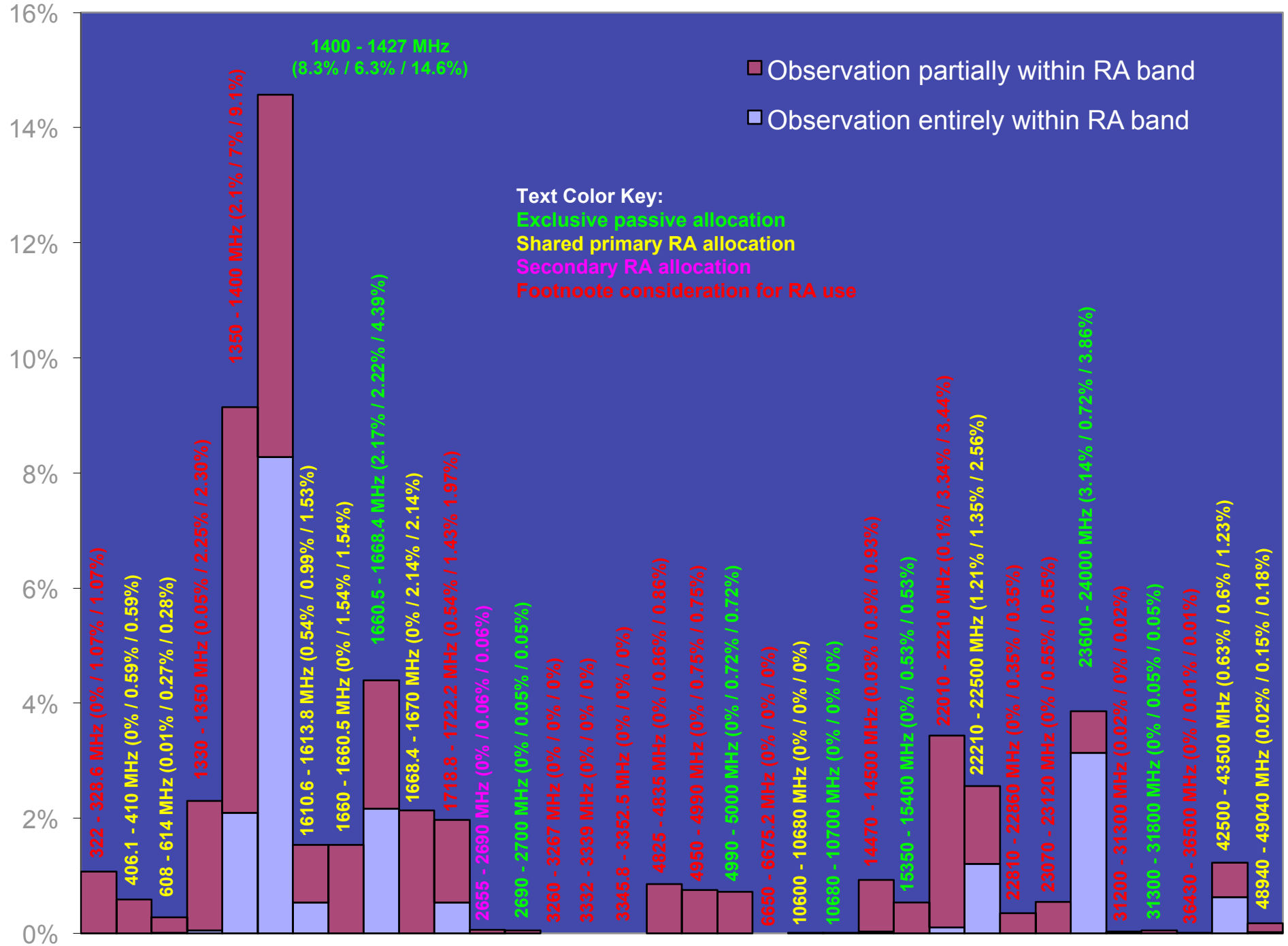
- "The Secretary of Commerce, working through NTIA, has been facilitating discussions between agencies and nonfederal entities that have produced an unprecedented level of information-sharing and collaboration to identify opportunities for agencies to relinquish or share spectrum"
- "The NTIA shall design and conduct a pilot program to monitor spectrum usage in real time in selected communities throughout the country to determine whether a comprehensive monitoring program in major metropolitan areas could disclose opportunities for more efficient spectrum access, including via sharing."

Conclusion (although there are more slides left, sorry)

- U.S. takes spectrum sharing very seriously, and even the military, aviation, weather radars, and weather satellites are not immune
- Radio astronomy is not immune either
  - Better for the radio astronomy community to be pro-active in identifying bands to share
  - Channel 37 is a good first step


GBT Fraction of Time Observing per 1 MHz Bin over the Period 2003-2011
(Blatnik, Clegg, Maddalena, & Beaudet)
Frequency Histogram (0-30,000 MHz)
Percentage of total GBT observing time, per 1 MHz bin
Frequency (MHz)
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
2,500
5,000
7,500
10,000
12,500
15,000
17,500
20,000
22,500
25,000
27,500
30,000
L-Band
S-Band
PF2
PF1
C-Band
X-Band
Ku-Band
K-Band (lower)
K-Band (upper)
Ka-Band (MM-F1)


Frequency Histogram (0-3,000 MHz)
PF1, PF2, L-Band, and S-Band
HI observing at 1420.4 MHz
No Allocation
Exclusive Passive
Shared Primary
Secondary
Footnote
Percentage of total GBT observing time, per 1 MHz bin
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
250
500
750
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
3,000
Frequency (MHz)

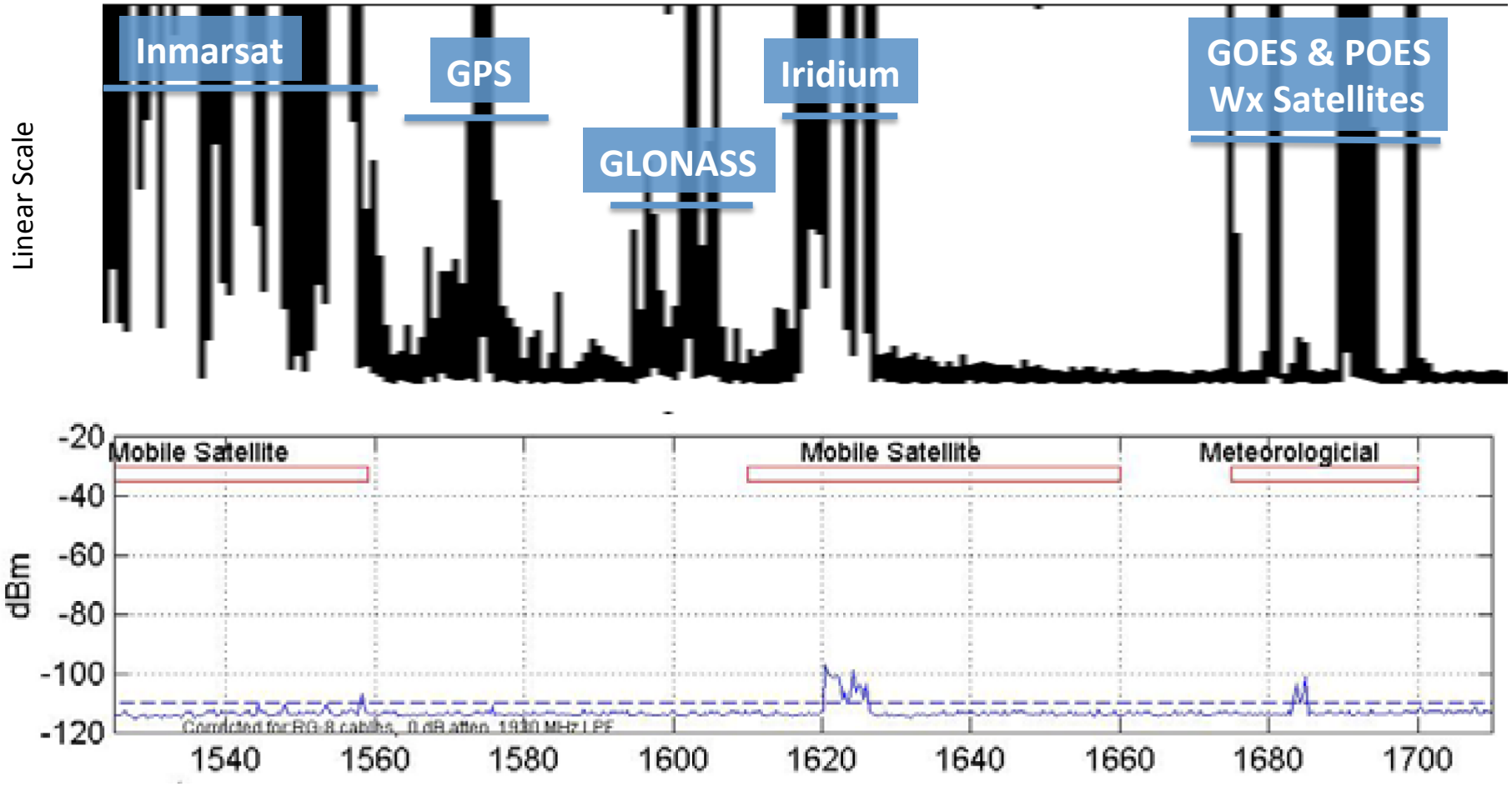

16%
14%
12%
10%
8%
6%
4%
2%
0%
Observation partially within RA band
Observation entirely within RA band
Text Color Key:
Exclusive passive allocation
Shared primary RA allocation
Secondary RA allocation
Footnoote consideration for RA use
1400 - 1427 MHz
(8.3% / 6.3% / 14.6%)
322 - 328.6 MHz (0% / 1.07% / 1.07%)
406.1 - 410 MHz (0% / 0.59% / 0.59%)
608 - 614 MHz (0.01% / 0.27% / 0.28%)
1330 - 1350 MHz (0.05% / 2.25% / 2.30%)
1350 - 1400 MHz (2.1% / 7% / 9.1%)
1610.6 - 1613.8 MHz (0.54% / 0.99% / 1.53%)
1660 - 1660.5 MHz (0% / 1.54% / 1.54%)
1660.5 - 1668.4 MHz (2.17% / 2.22% / 4.39%)
1668.4 - 1670 MHz (0% / 2.14% / 2.14%)
1718.8 - 1722.2 MHz (0.54% / 1.43% 1.97%)
2655 - 2690 MHz (0% / 0.06% / 0.06%)
2690 - 2700 MHz (0% / 0.05% / 0.05%)
3260 - 3267 MHz (0% / 0% / 0%)
3332 - 3339 MHz (0% / 0% / 0%)
3345.8 - 3352.5 MHz (0% / 0% / 0%)
4825 - 4835 MHz (0% / 0.86% / 0.86%)
4950 - 4990 MHz (0% / 0.73% / 0.73%)
4990 - 5000 MHz (0% / 0.72% / 0.72%)
6650 - 6675.2 MHz (0% / 0% / 0%)
10600 - 10680 MHz (0% / 0% / 0%)
10680 - 10700 MHz (0% / 0% / 0%)
14470 - 14500 MHz (0.03% / 0.9% / 0.93%)
15350 - 15400 MHz (0% / 0.53% / 0.53%)
22010 - 22210 MHz (0.1% / 3.34% / 3.44%)
22210 - 22500 MHz (1.21% / 1.35% / 2.56%)
22810 - 22860 MHz (0% / 0.35% / 0.35%)
23070 - 23120 MHz (0% / 0.55% / 0.55%)
23600 - 24000 MHz (3.14% / 0.72% / 3.86%)
31200 - 31300 MHz (0.02% / 0% / 0.02%)
31300 - 31800 MHz (0% / 0.05% / 0.05%)
36430 - 36500 MHz (0% / 0.01% / 0.01%)
42500 - 43500 MHz (0.63% / 0.6% / 1.23%)
48940 - 49040 MHz (0.02% / 0.15% / 0.18%)

What do Radio Astronomers Have to Offer

- Appropriate frequency bands on a shared basis (TBD)
- Knowledge of dynamic frequency scheduling and its application to/integration with dynamic spectrum access databases
- Expertise in spectrum monitoring
  - Especially weak-signal occupancy measurements

Comparison of “normal” and radio astronomy spectrum monitoring data

Measurements through Green Bank Telescope RFI Monitor



Shared Spectrum Co. measurements at Green Bank site

Examples of U.S. Commercial and Academic Spectrum Observatories

- Illinois Institute of Technology Spectrum Observatory (funded by NSF)
  - http://www.cse.sc.edu/event/iits-spectrum-observatory
- Microsoft Spectrum Observatory
  - http://observatory.microsoftspectrum.com/

Conclusions & Recommendations

- Spectrum sharing is becoming the norm, and no services are immune
- Radio astronomy community should
  - Integrate dynamic observing scheduling into dynamic spectrum access databases
  - Examine RA bands for potential sharing opportunities
  - Contribute weak-signal spectrum monitoring data

IEEE Proceedings Special Issue on Future Spectrum Access

- Recommended reading
- Co-editors: Clegg & Weisshaar
- Famous contributing author:
  - Dr. Tomas Gergely
  - "Spectrum Access for the Passive Services: The Past and the Future"
- Full issue available at:
  - http://ieeexplore.ieee.org/xpl/tocresult.jsp?isnumber=6740864
  - Requires subscription (sorry)