Picking The Wrong Frequencies Can Cost/Harm You!

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NSF ERC Program Director

webinar: ***Intro to RF Spectrum Regulations***

Outline

- Motivation
- Radio Regulations
  - International Level
  - National Level
- Selecting a Frequency
  - NSF Spectrum Managers
- Acronyms & Concepts
- Conclusion

Penalties due to Lack of Awareness

Example:

In 2018, a cellphone company paid $614 million civil penalty to the FCC, for violating the radio regulation (RR) rules in connection with ~1,000 licenses.

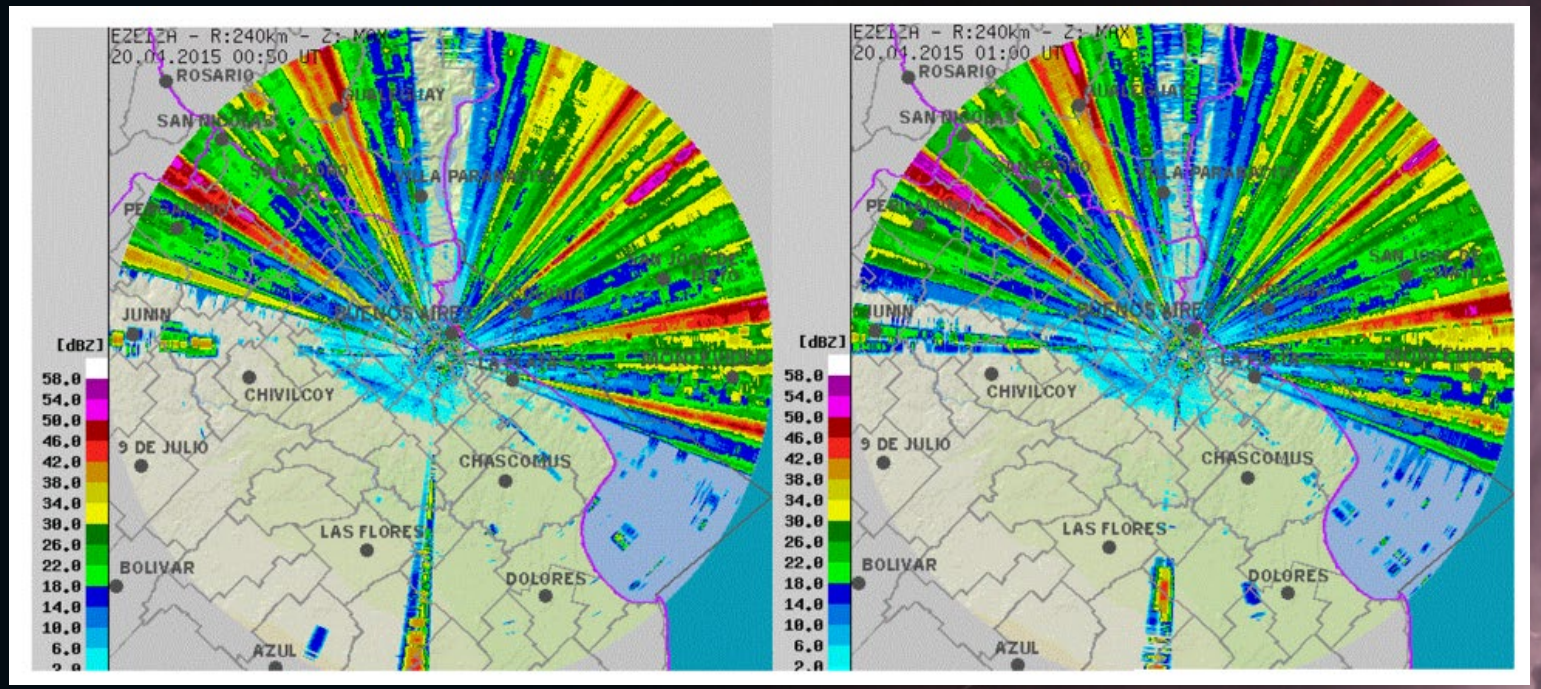
Did you know that…

- It's illegal to design a device to work at certain frequencies?

- You might need an *experimental license* for research that involves transmitting at some frequency bands?

- The UN has a body to help regulate *RF* signals used all over the World?

Airport Weather radar Interference Example



FCC penalties

Fined for Not Having Unobtainable **License**. FCC action follows interference to airport weather radar. The FCC has confirmed a **fine** of **$25,000** against for operating a Wi-Fi-type device that caused interference to a weather radar at a Puerto Rico airport. Oct 11, 2012

Fines for transmitting on the wrong frequency band or violating in any other way the Radio Regulations:

www.fcc.gov › enforcement › orders

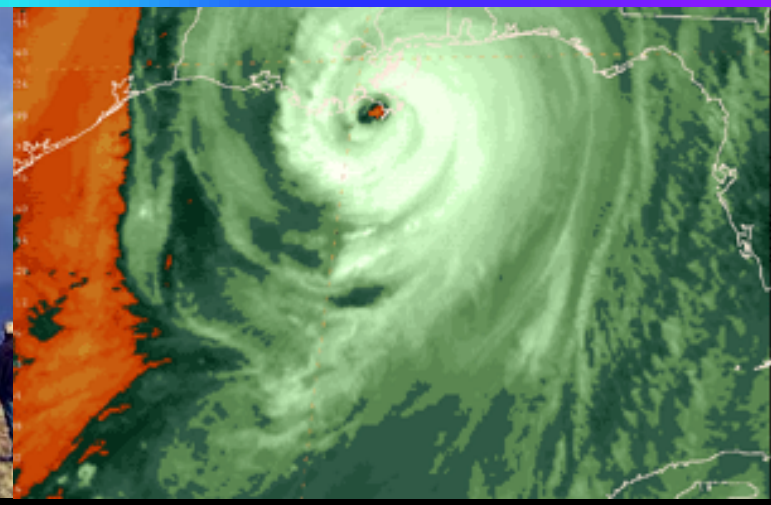
Orders | Federal Communications Commission

FCC Proposes $57.2M Fine against in Location Information Case.

The $144,344 fine is against the owners of a low-power station

The station failed to renew the license starting in 1998, and it was canceled in 2004.



- ✓ The RF Spectrum is a limited resource.
- ✓ RR are constantly evolving.

Wireless Medical Telemetry Service (WMTS)

Biomedical devices

Due to interference in **2002**, the radio regulations were updated and moved from 174-216 & 470-668MHz & 450-470 MHz to 608-614 , 1395-1400 and 1427-1432 MHz.

The Wireless Medical Telemetry Service (WMTS) is in the 608 – 614, 1395 – 1400, and 1427 – 1432 MHz range. WMTS spectrum is used for remote monitoring of a patient's health. Wireless medical telemetry

Wireless Medical Telemetry Service (WMTS)

Biomedical devices

Due to interference in **2002**, the radio regulations were updated and moved from 174-216 & 470-668MHz & 450-470 MHz to 608-614 , 1395-1400 and 1427-1432 MHz.

Prior to establishing the Wireless Medical Telemetry Service (WMTS), medical telemetry devices operated on an unlicensed basis on vacant television channels 7-13 (174-216 MHz) and 14-46 (470-668 MHz) or on a licensed, but secondary basis to private land mobile devices in the 450-470 MHz band. This meant that wireless telemetry devices had to accept interference from the television broadcasters and private land mobile licensees.

Concerns over additional interference to medical telemetry devices became a greater issue as the transition from analog to digital television began. To help alleviate additional interference to wireless medical telemetry devices, the FCC took action to establish the Wireless Medical Telemetry Service (WMTS) in 2002 by allocating 14 MHz of spectrum for wireless medical telemetry.

Webinar Objectives

1. Learn Basic Concepts of RFSM (Radio Frequency Spectrum Management)

2. Learn basic Radio Regulation (RR) principles
   - how you can select the appropriate frequency

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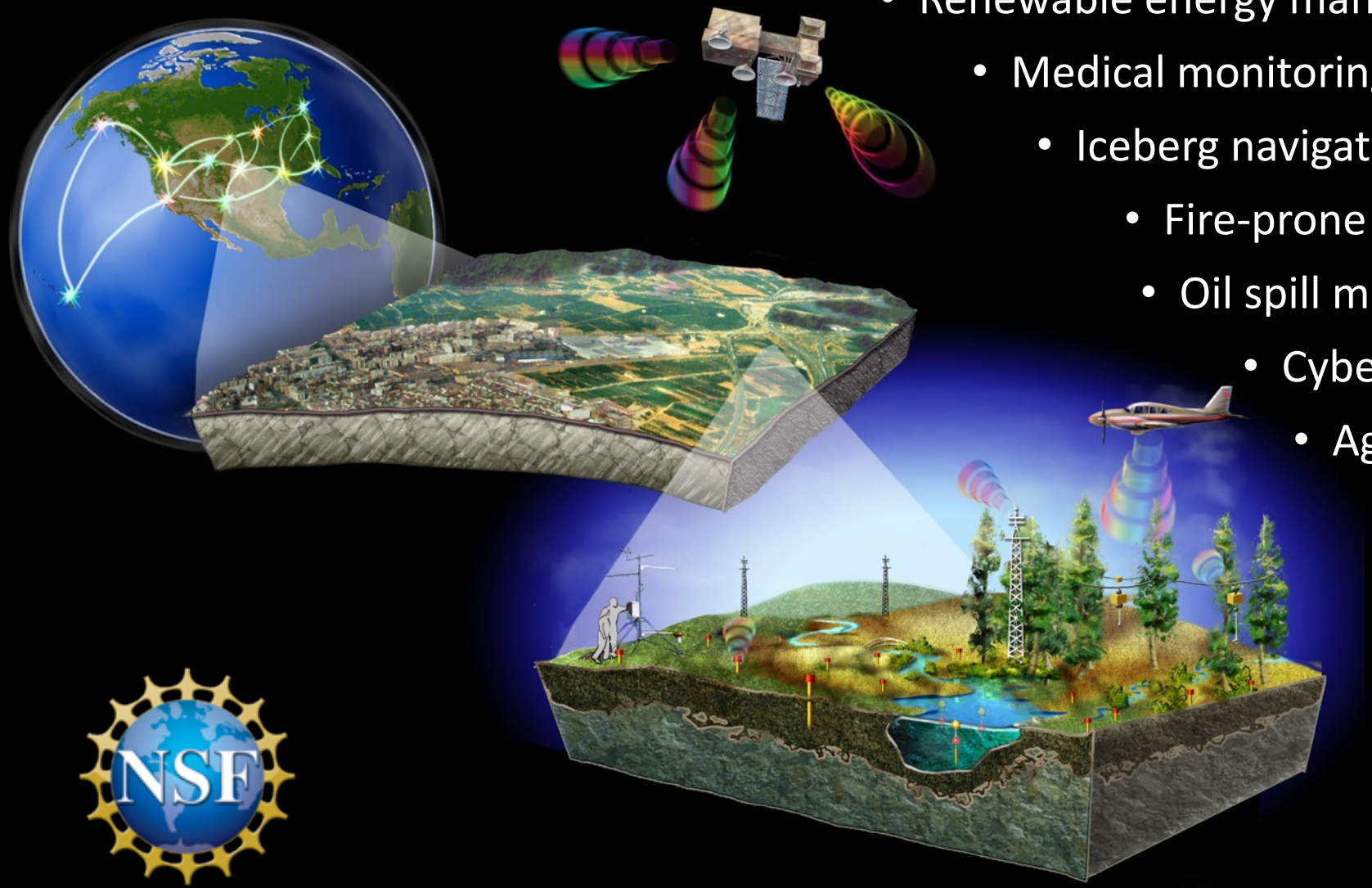
Imagine a World w/o RF

Without Regulation the RF Interference could render your device unusable!

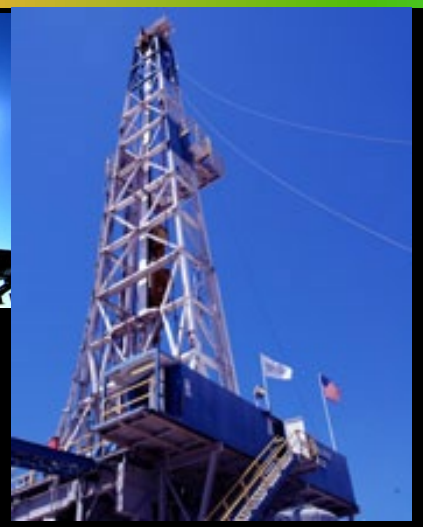
- No data on hurricane monitoring
- No Postal packages tracking
- No 5 days Weather forecasting
- No GPS navigation system
- No Solar storms prediction
  - (Energy grid disruption)
- No cellphones! No text, calls…
- Satellite TV, Wi-Fi internet, AM and FM radio, broadcast TV ,…

Science & Engineering Uses could be affected by RFI

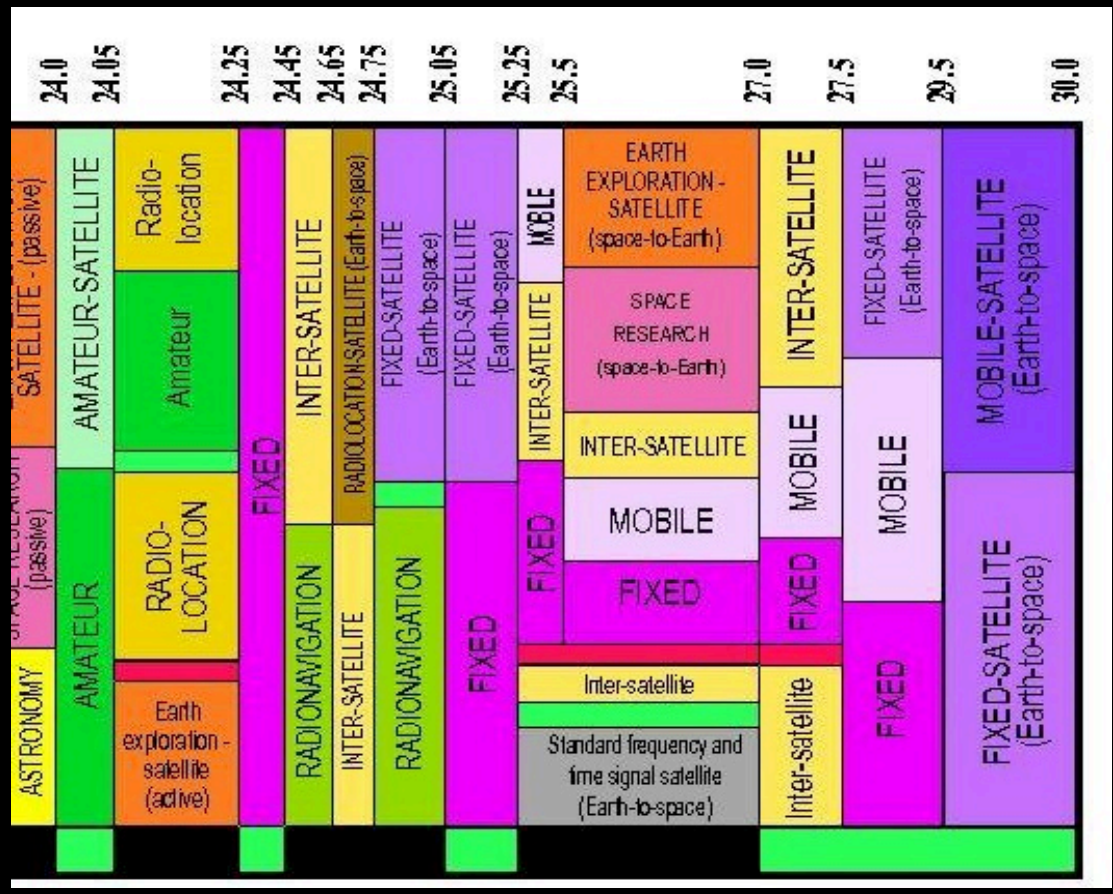
- El Niño Southern Oscillation monitoring
- Renewable energy management
- Medical monitoring devices
- Iceberg navigation maps
- Fire-prone mapping
- Oil spill monitoring
- Cybersecurity
- Agriculture



What is Spectrum Management?

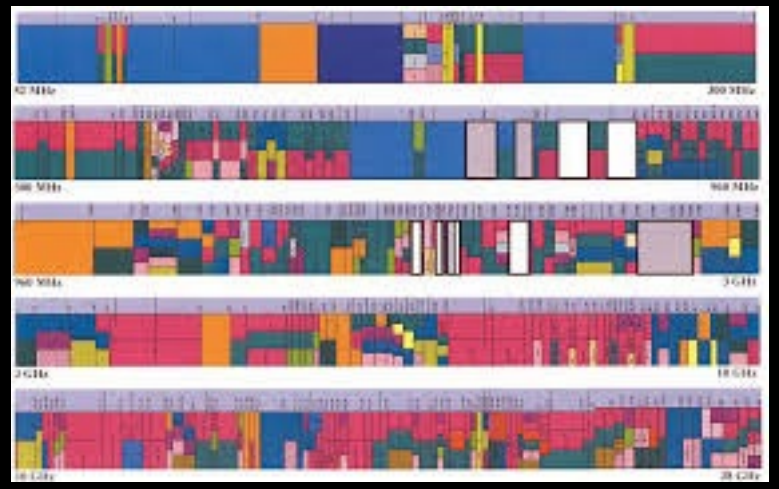


Spectrum management is the process of regulating the use of RF to promote efficient use and gain a net social benefit.

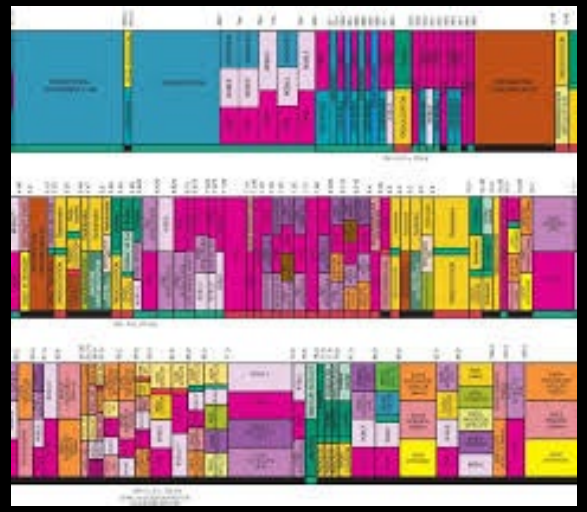


Example of RF Spectrum section for the US Table of Frequency Allocations

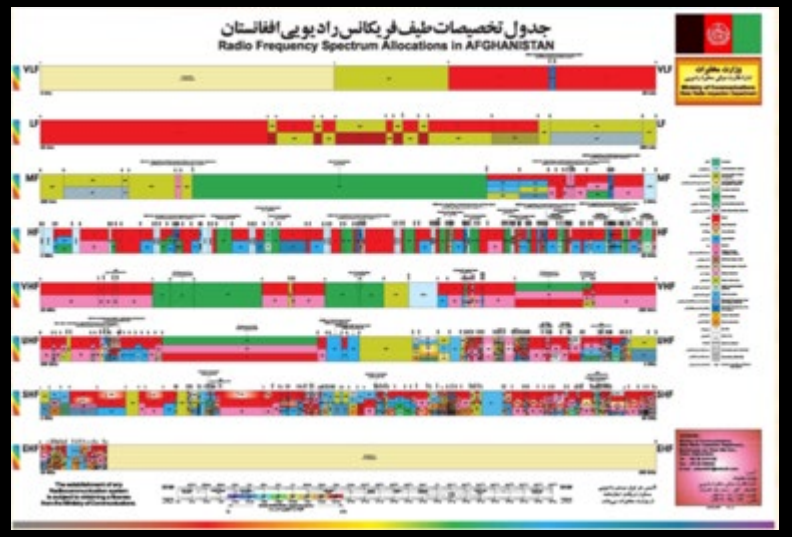
Frequency Allocation Table (FAT) examples



Canada



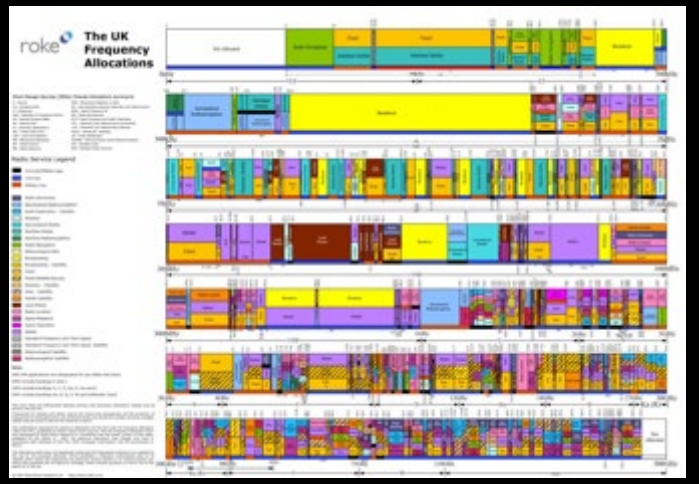
Australia



Afghanistan

South Africa

EU

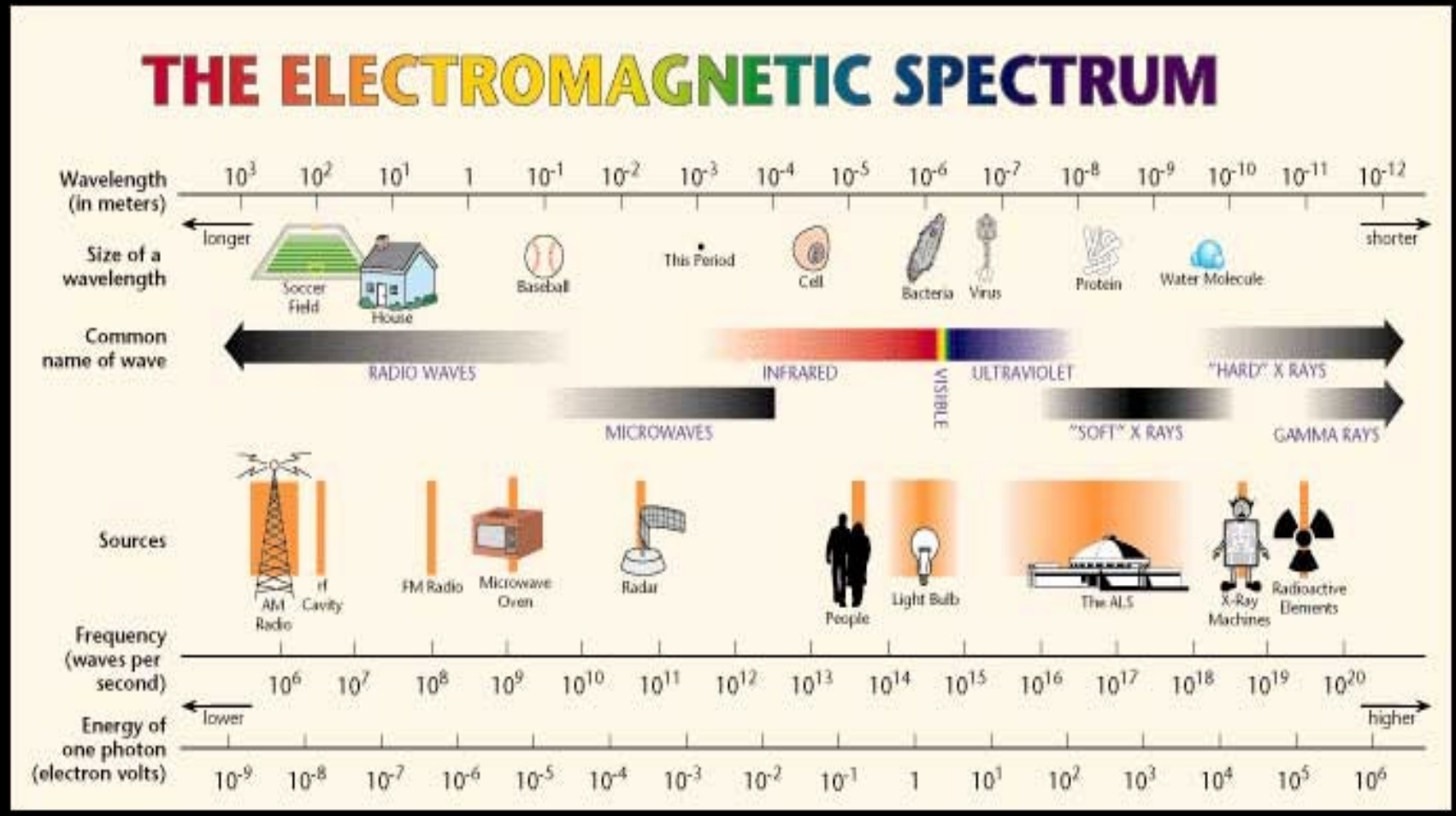


UK

Globalization Challenges

- Used to block signals, but also RFI to airport weather radars
- Easy to buy online
- Fines of up to over $100,000 per violation and could lead to criminal prosecution or seizure of the device.

RF Spectrum Definition



UN ITU: 3kHz to 3THz

(ITU Radio Regulations, Art. 2 § I 2016)

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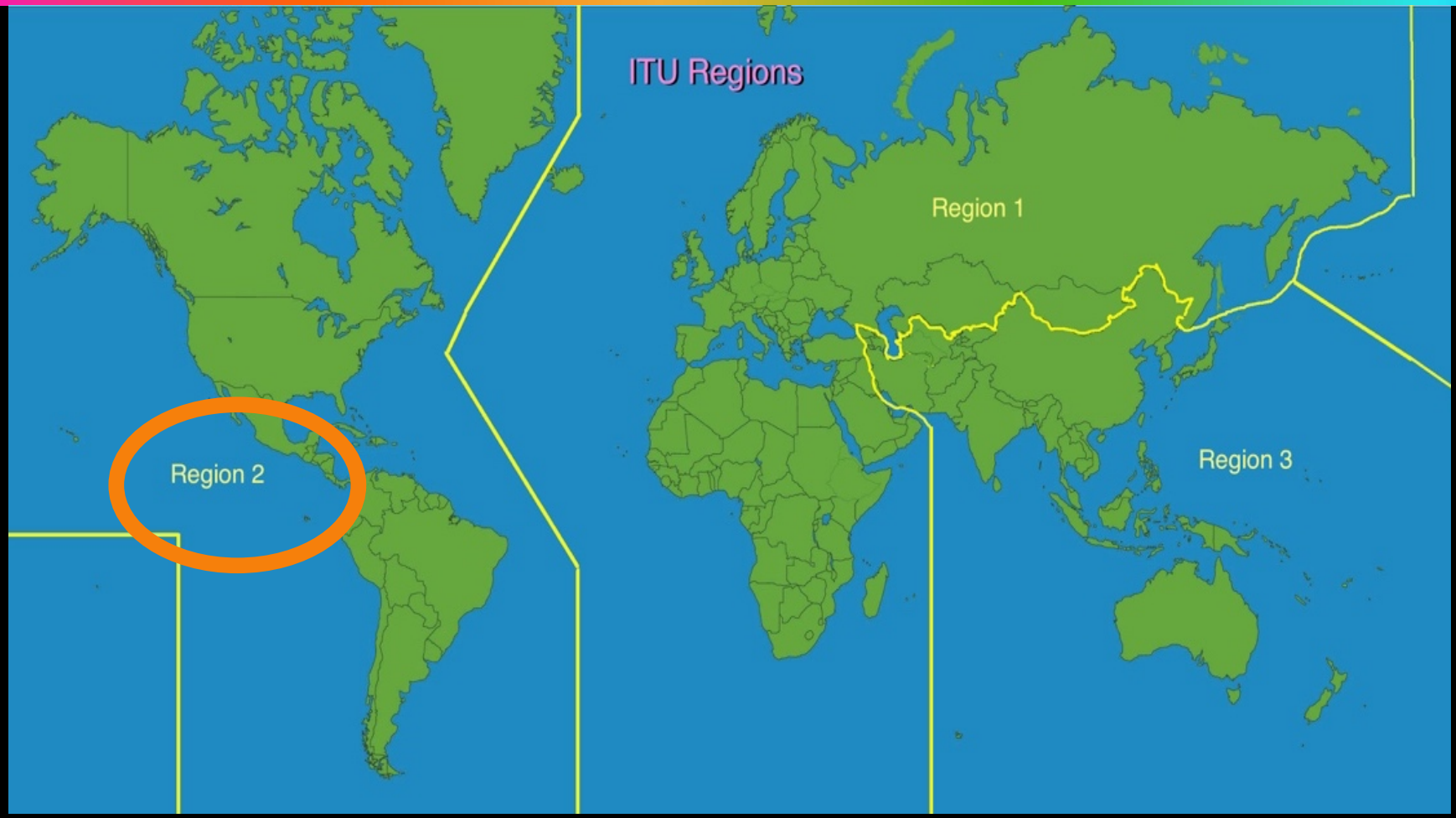
UN – ITU

International Telecommunication Union

ITU Regions



WRC
World Radiocommunication Conference

International meeting to revise the RR

- ✓Every 3-4 years
- ✓Lasts ~4 weeks

ITU-R RR & Rec.

- Radio Regulations (RR) are agreed to by International Treaty
- Rec.=Recommendations are typically non-mandatory

  (unless incorporated by reference into the RR)

Rec. ITU-R S.672-4

RECOMMENDATION ITU-R S.672-4*

Satellite antenna radiation pattern for use as a design objective in the fixed-satellite service employing geostationary satellites

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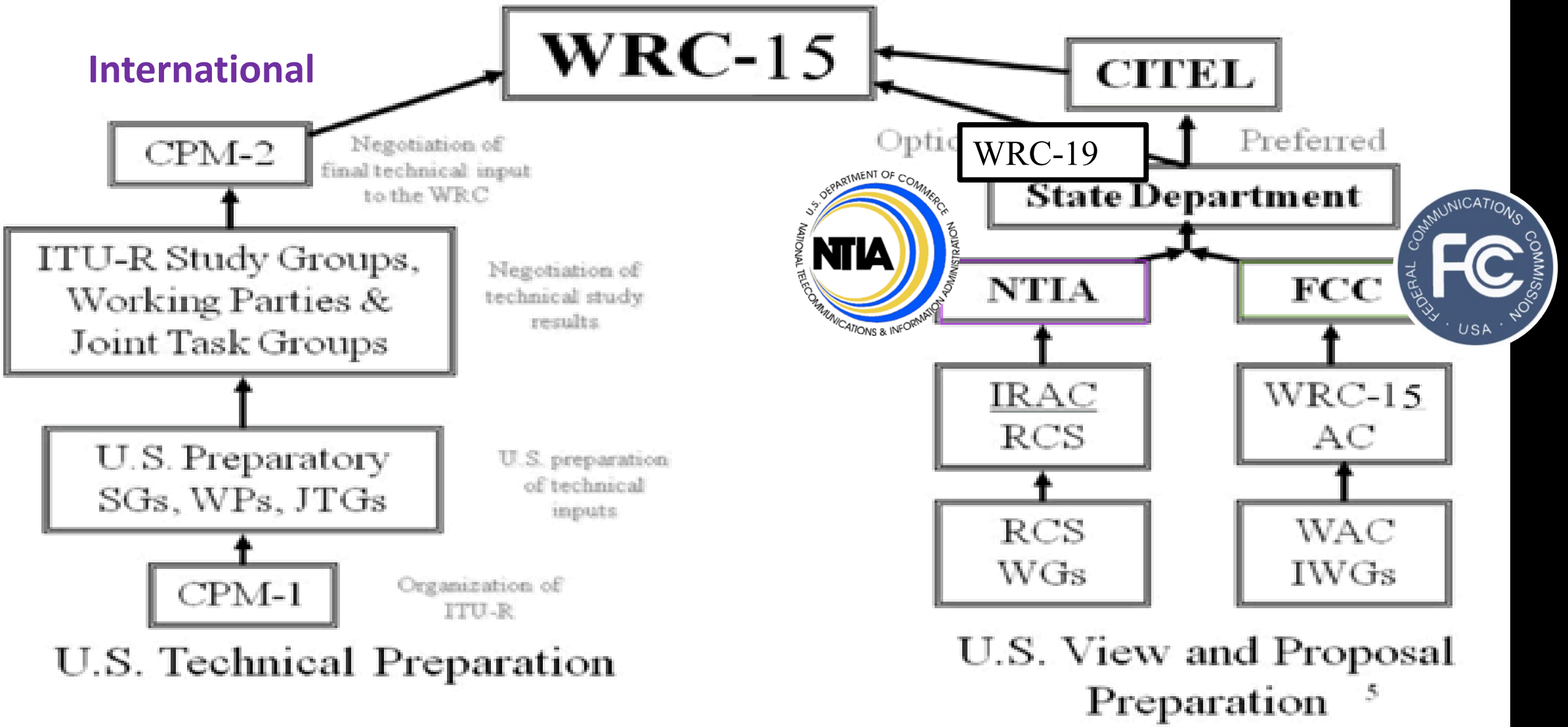
US Spectrum Regulation Agencies

- U.S. is special Case
  1. FCC
     - NonFed-licenses
  2. NTIA
     - Federal-assignments

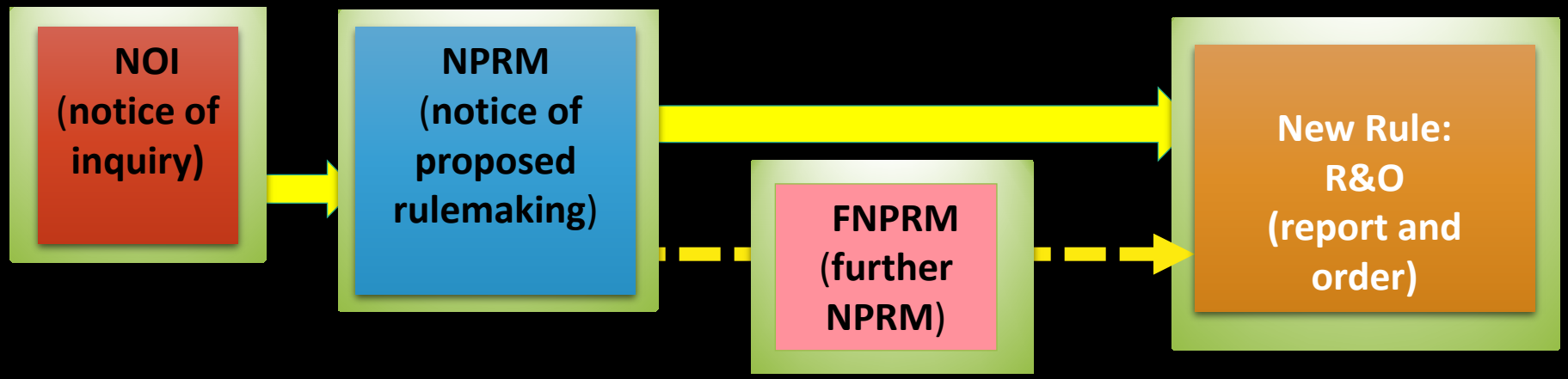
U.S. Preparatory Process

International



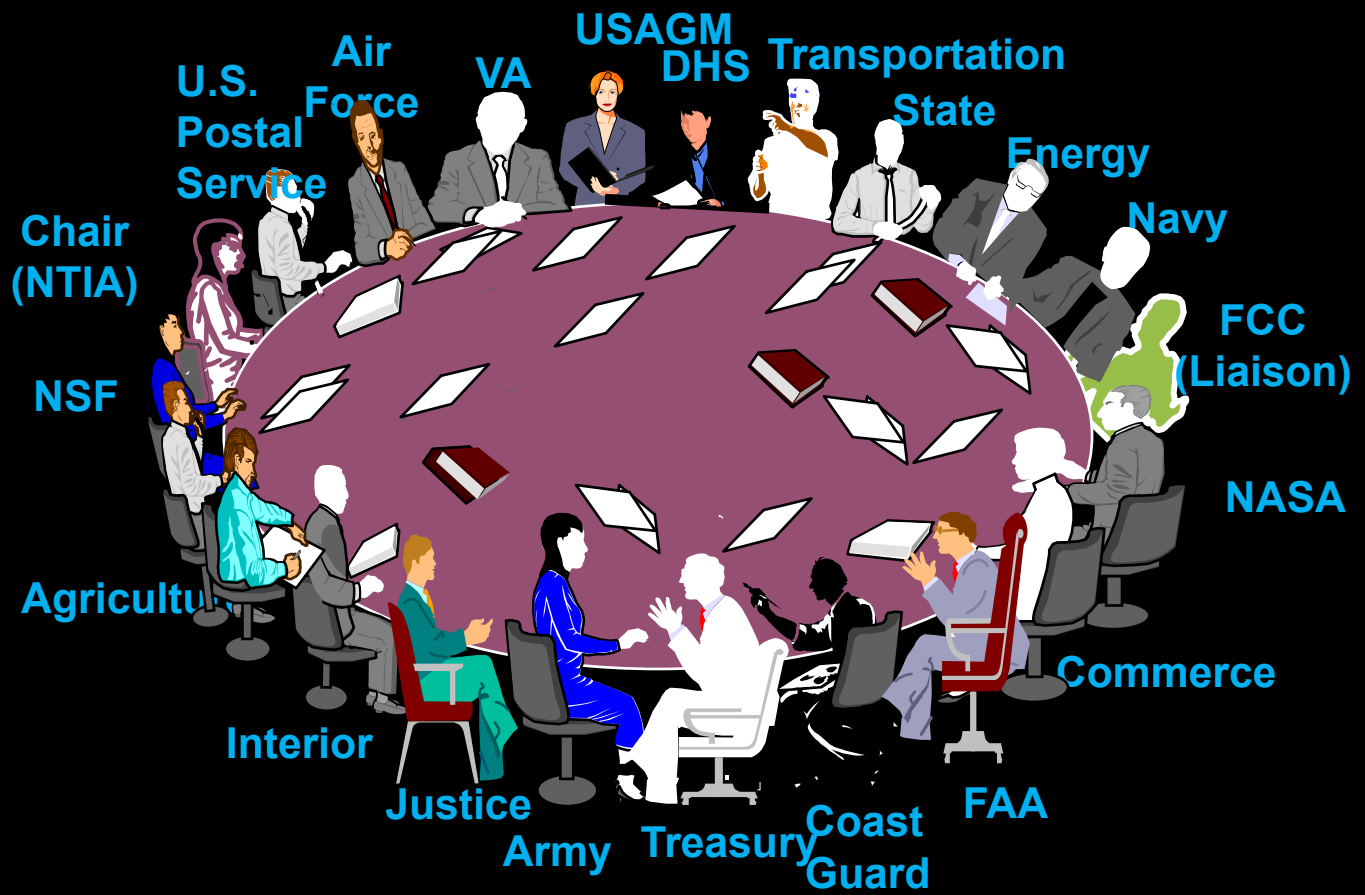
Notice and Comment Rulemaking

- Used to publish any proposal to change the RF spectrum regulations in the US and seek comments.
- Typically gives
  - 60 days for public comment from any interested party,
  - and an additional 30 days for reply comments.

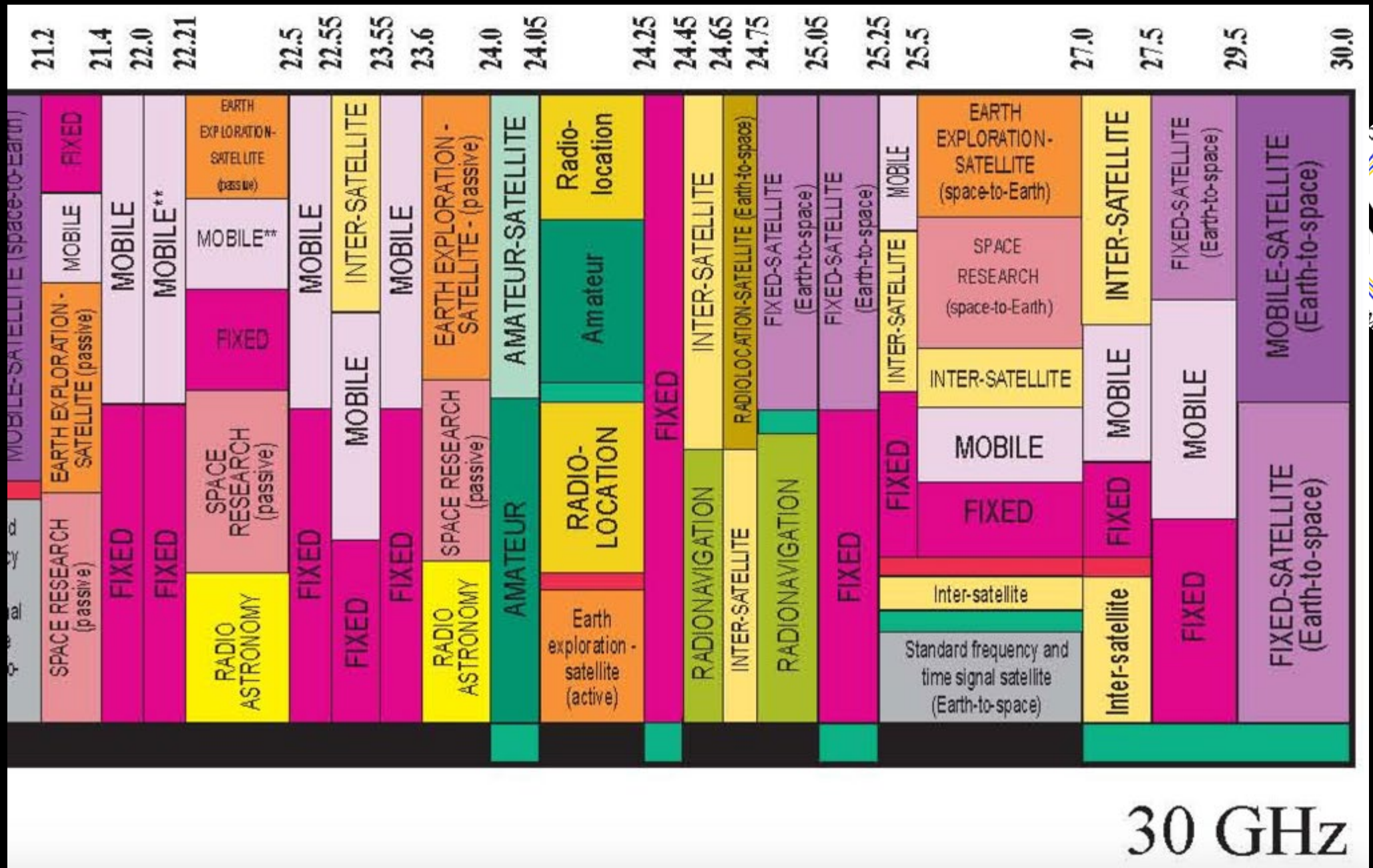


The Interdepartment Radio Advisory Committee (IRAC)

- Chaired by the NTIA:
- Representatives from all federal agencies that use the spectrum and a Liaison from the FCC



Frequency Allocation Table (FAT) Closer Look Example



Footnotes

- Allocation Footnotes:
  - 5.xxx: ITU footnotes. When they appear in the U.S. tables, it means that they have been adopted in the FCC and/or NTIA tables
  - USxxx: Footnotes that apply to both Federal and non-Federal allocations
  - NGxxx: Footnotes that apply only to non-federal-government allocations
  - Gxxx: Footnotes that apply only to federal government allocations

US385 Radio astronomy observations may be made in the bands 1350-1400 MHz, 1718.8-1722.2 MHz, and 4950-4990 MHz on an unprotected basis, and in the band 2655-2690 MHz on a secondary basis, at the following radio astronomy observatories:

Allen Telescope Array, Hat Creek, CA	Rectangle between latitudes 40° 00' N and 42° 00' N and between longitudes 120° 15' W and 122° 15' W.	
NASA Goldstone Deep Space Communications Complex, Goldstone, CA	80 kilometers (50 mile) radius centered on 35° 20' N, 116° 53' W.	
National Astronomy and Ionosphere Center, Arecibo, PR	Rectangle between latitudes 17° 30' N and 19° 00' N and between longitudes 65° 10' W and 68° 00' W.	
National Radio Astronomy Observatory, Socorro, NM	Rectangle between latitudes 32° 30' N and 35° 30' N and between longitudes 106° 00' W and 109° 00' W.	
National Radio Astronomy Observatory, Green Bank, WV	Rectangle between latitudes 37° 30' N and 39° 15' N and between longitudes 78° 30' W and 80° 30' W.	
National Radio Astronomy Observatory, Very Long Baseline Array Stations	80 kilometer radius centered on:	
	North latitude	West longitude
Brewster, WA	48° 08'	119° 41'
Fort Davis, TX	30° 38'	103° 57'
Hancock, NH	42° 56'	71° 59'
Kitt Peak, AZ	31° 57'	111° 37'
Los Alamos, NM	35° 47'	106° 15'
Mauna Kea, HI	19° 48'	155° 27'
North Liberty, IA	41° 46'	91° 34'
Owens Valley, CA	37° 14'	118° 17'
Pie Town, NM	34° 18'	108° 07'
Saint Croix, VI	17° 45'	64° 35'
Owens Valley Radio Observatory, Big Pine, CA	Two contiguous rectangles, one between latitudes 36° 00' N and 37° 00' N and between longitudes 117° 40' W and 118° 30' W and the second between latitudes 37° 00' N and 38° 00' N and between longitudes 118° 00' W and 118° 50' W.	

(a) In the bands 1350-1400 MHz and 4950-4990 MHz, every practicable effort will be made to avoid the assignment of frequencies to stations in the fixed and mobile services that could interfere with radio astronomy observations within the geographic areas given above. In addition, every practicable effort will be made to avoid assignment of frequencies in these bands to stations in the aeronautical mobile service which operate outside of those geographic areas, but which may cause harmful interference to the listed observatories. Should such assignments result in harmful interference to these observatories, the situation will be remedied to the extent practicable.

(b) In the band 2655-2690 MHz, for radio astronomy observations performed at the locations listed above, licensees are urged to coordinate their systems through the Electromagnetic Spectrum Management Unit, Division of Astronomical Sciences, National Science Foundation, Room 1030, 4201 Wilson Blvd., Arlington, VA 22230.

Footnotes

5.133B

Stations in the amateur service using the frequency band 5 351.5-5 366.5 kHz shall not exceed a maximum radiated power of 15 W (e.i.r.p.). However, in Region 2 in Mexico, stations in the amateur service using the frequency band 5 351.5-5 366.5 kHz shall not exceed a maximum radiated power of 20 W (e.i.r.p.). In the following Region 2 countries: Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Dominica, El Salvador, Ecuador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela, as well as the overseas territories of the Netherlands in Region 2, stations in the amateur service using the frequency band 5 351.5-5 366.5 kHz shall not exceed a maximum radiated power of 25 W (e.i.r.p.). (WRC-15)

5.138

The following bands:

6765-6795 kHz (centre frequency 6780 kHz),

433.05434.79 MHz (centre frequency 433.92 MHz) in Region 1 except in the countries mentioned in No. 5.280

6161.5 GHz (centre frequency 61.25 GHz),

122-123 GHz (centre frequency 122.5 GHz), and

244-246 GHz (centre frequency 245 GHz)

are designated for *industrial, scientific and medical (ISM) applications*. The use of these frequency bands for ISM applications shall be subject to special authorization by the administration concerned, in agreement with other administrations whose radiocommunication

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How to pick a frequency?

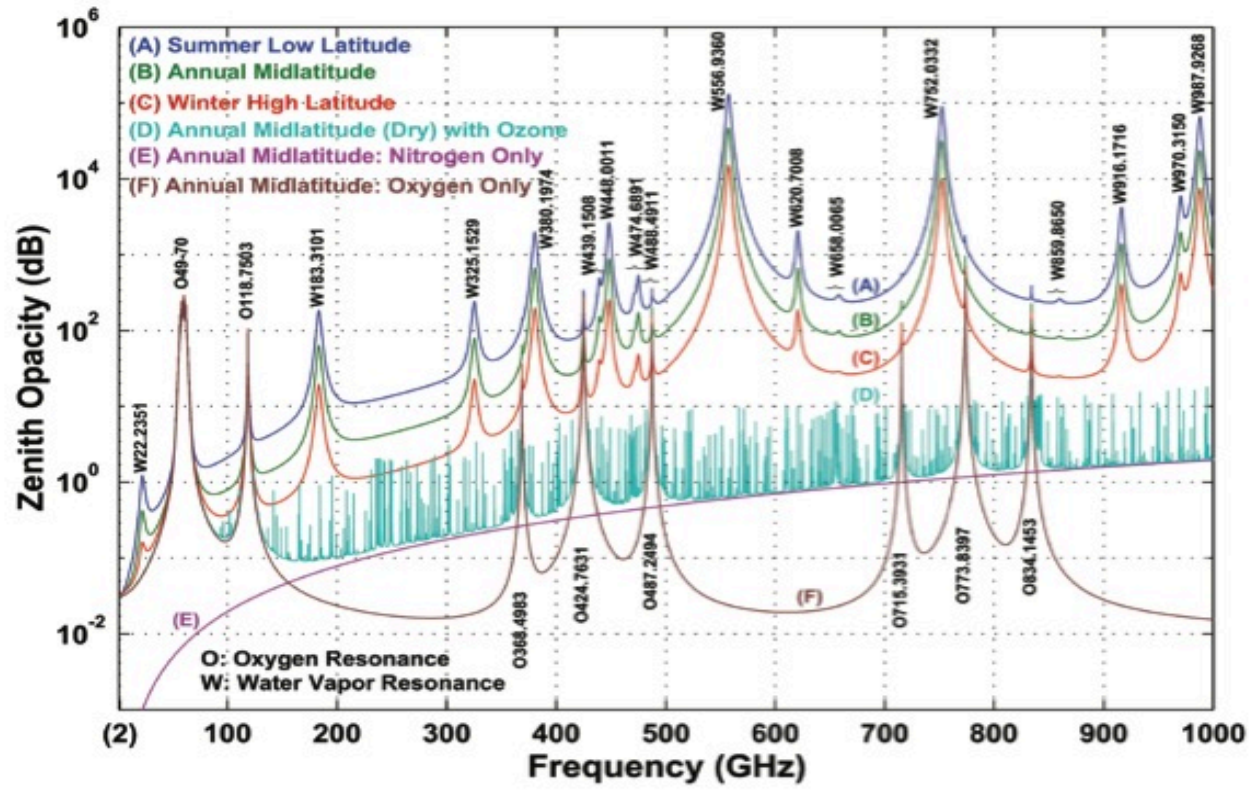

FIGURE 1.2 The opacity of Earth's atmosphere in the radio range of frequencies from 1 to 1000 GHz for six scenarios. Image courtesy of A.J. Gasiewski, University of Colorado.

How to pick a frequency?

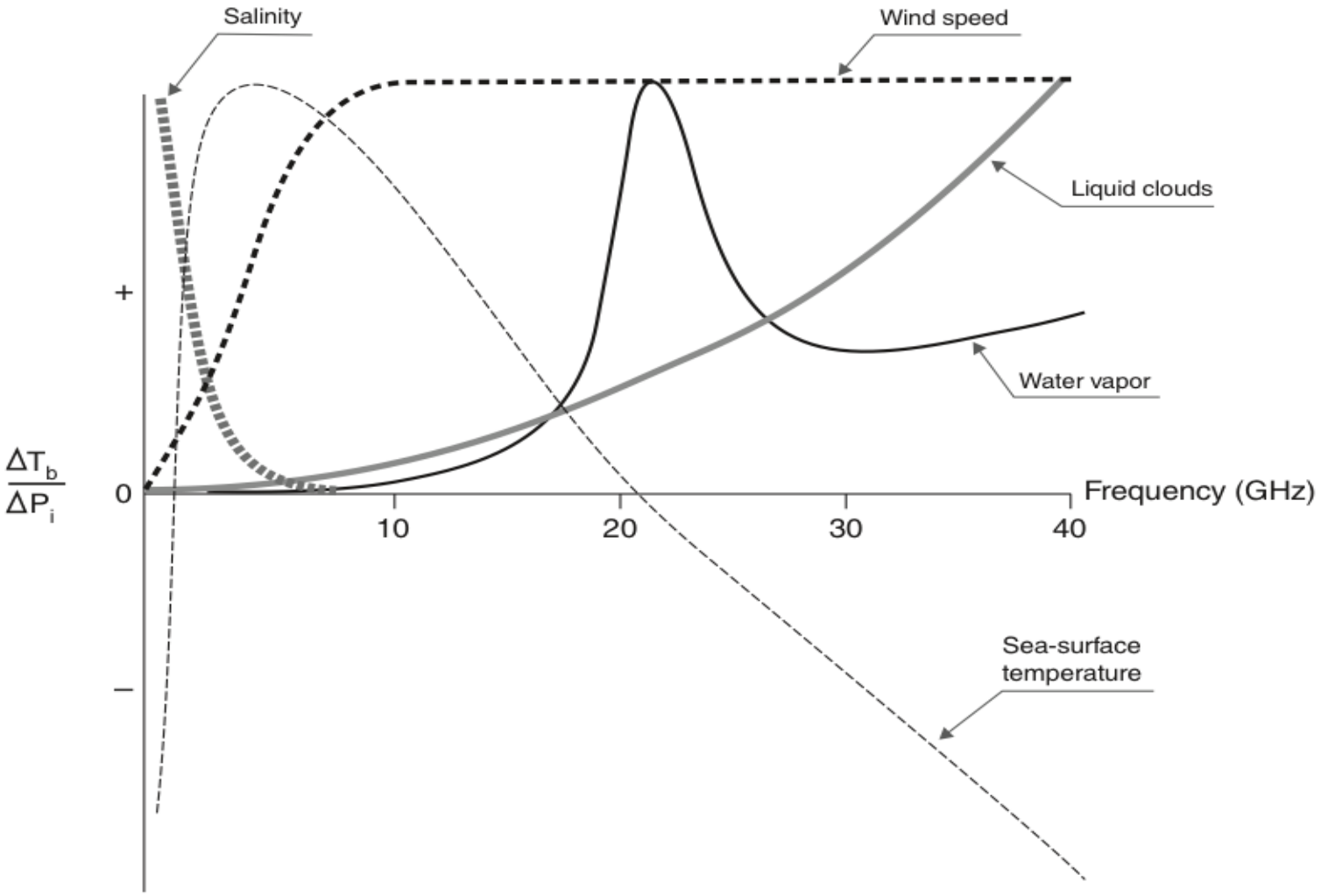

FIGURE 2.11 Ocean scene: relative sensitivity of sea surface salinity, sea surface temperature, cloud liquid water, and integrated water vapor as a function of frequency for space-based measurements. Original figure by Thomas T. Wilheit, NASA-GSFC.

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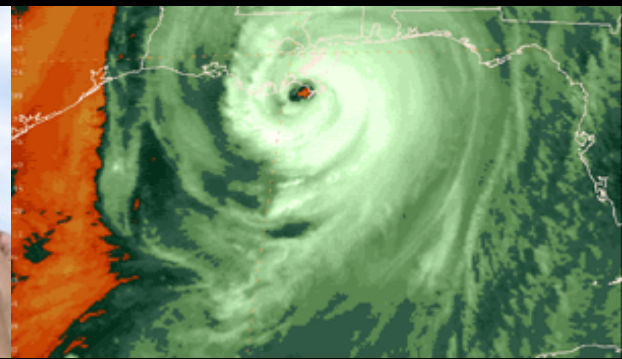
Spectrum Managers

At: Boeing, Nokia, Google, SpaceX, …

NASA, NOAA, DoI, DoD, FAA, Navy…



NSF has 2 Spectrum Managers

NSF's Electromagnetic Spectrum Management (ESM) Unit

B. Ashley Zauderer
bezauder@nsf.gov

Jonathan V. Williams
jonwill@nsf.gov

Contact for assistance with frequency assignments or questions:

ESM@nsf.gov

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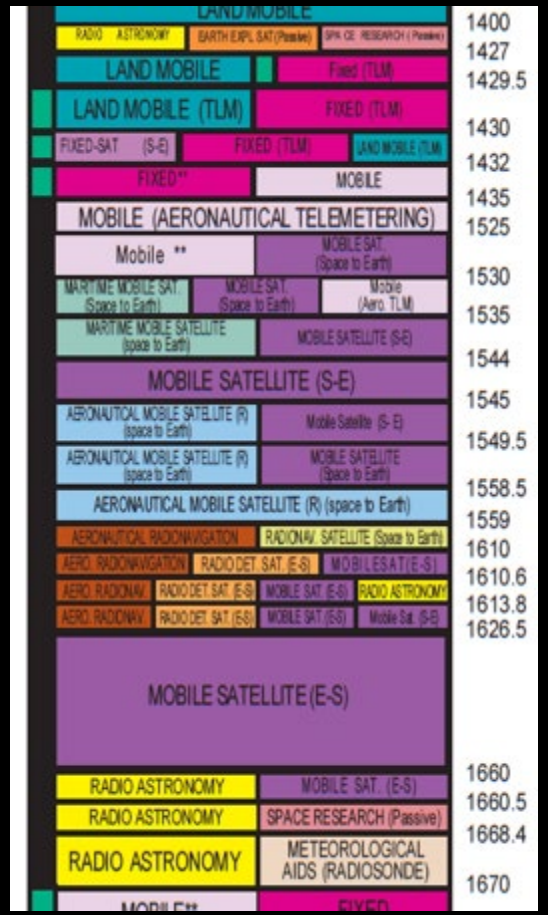
Allocation vs. Assignment

Analogous to zones in a city:

Credit: Taylor's Univ. Malaysia



Allocation Types

- **Primary allocations** grant specific services priority in using a particular region of allocated spectrum. In cases where there are multiple primary services within a band, they have equal rights. A station has the right to be protected from any others that start operation at a later date.
- **Secondary allocations** involve services that must protect all primary allocations in a particular band. Services operating in secondary allocations must not cause harmful interference to, and must accept interference from, primary users. All secondary service stations have equal rights among themselves in the same band.

UNII

Unlicensed National Information Infrastructure

Unlicensed means that devices can use this band to transmit and/or receive without a license. * Varies by country.

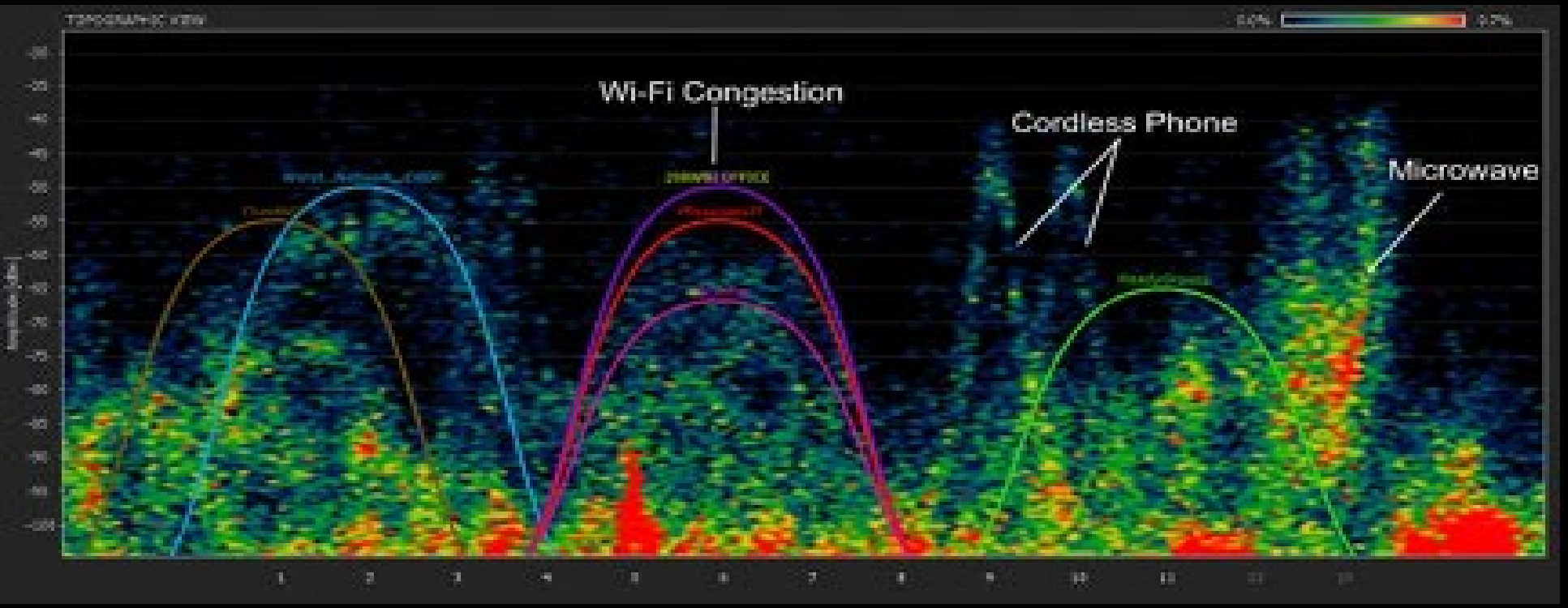
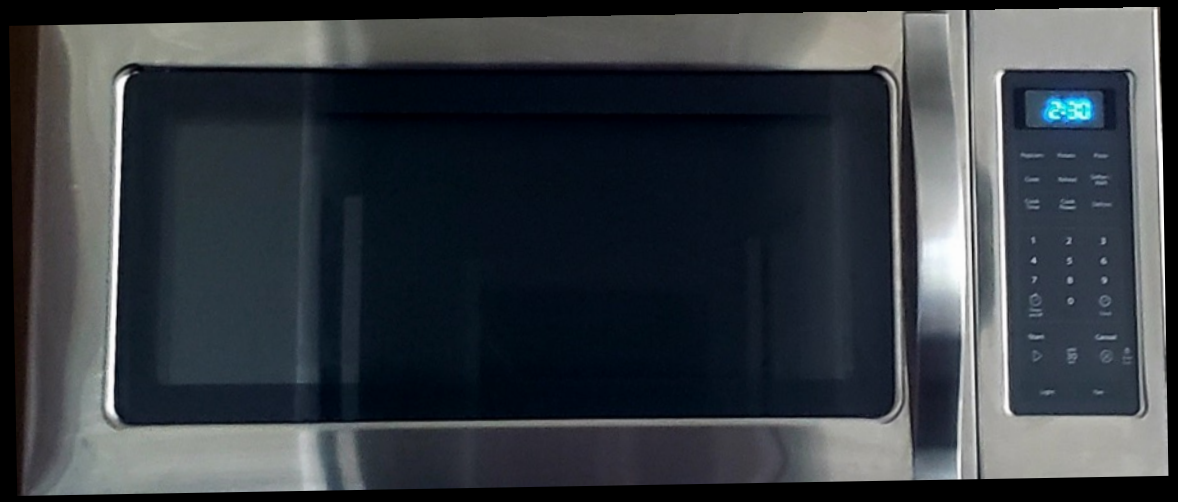


Image from Metageek.com

UNII bands in the U.S.

Band Name(s)	Frequency range
U-NII-1 or UNII Low	5.150-5.250 GHz
U-NII-2A	5.250-5.350 GHz
U-NII-2B	5.350-5.470 GHz (need license)
U-NII-2C / U-NII-2e or U-NII Worldwide* *not used in China or Israel	5.470-5.725 GHz -subject to Dynamic Frequency Selection (DFS) for radar avoidance.
U-NII -3 or U-NII Upper	5.725 to 5.850 GHz, overlaps with ISM
U-NII-4	5.850 to 5.925 GHz (Amateur)

Microwave ovens



- Use 2.45 GHz (within S-band)
- Guard band to reduce RFI with adjacent bands
  - 2.4-to-2.4835-GHz ISM band was born.

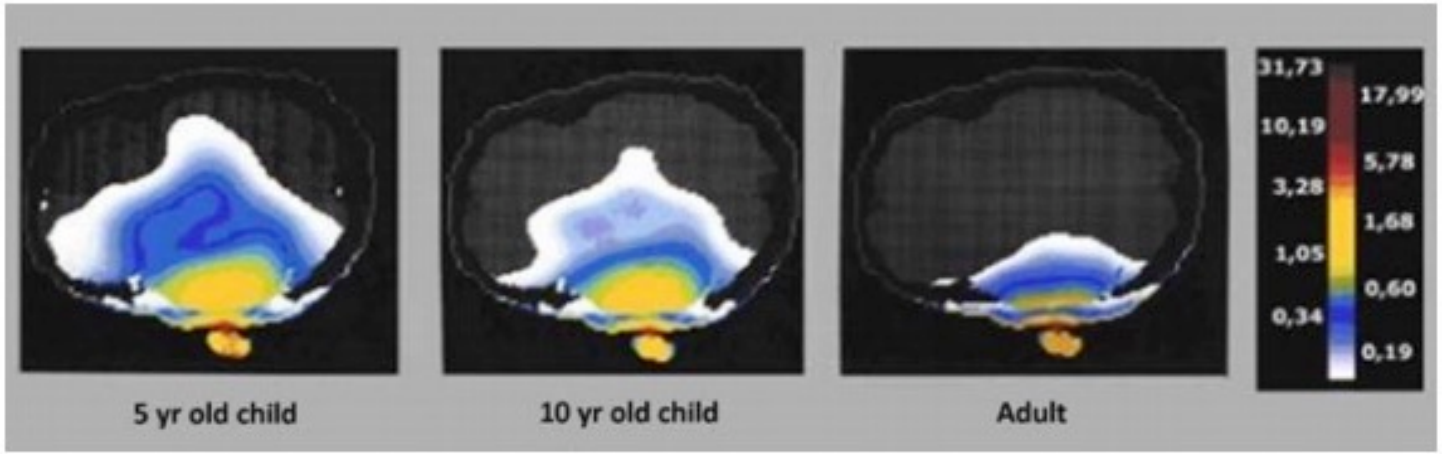
ISM (unlicensed)
Industrial, Scientific, and Medical

Examples: Microwave ovens at 2.45Ghz

- Cancer Treatment -Radiation at several ISM frequencies for medical diathermy
- Cordless phones
- Internet of Things (IoT) devices
- Bluetooth devices (2.4GHz)
- Wi-Fi on 2.4-GHz and 5GHz
- Walkie-talkies at 900-Mhz
- Cellphones (GSM) operating at some ISM bands
- Radio Frequency Identification Device (RFID)

They all share several ISM bands without any regulatory protection from RFI from each other.

SAR [W/kg]
Specific, Absorption Rate

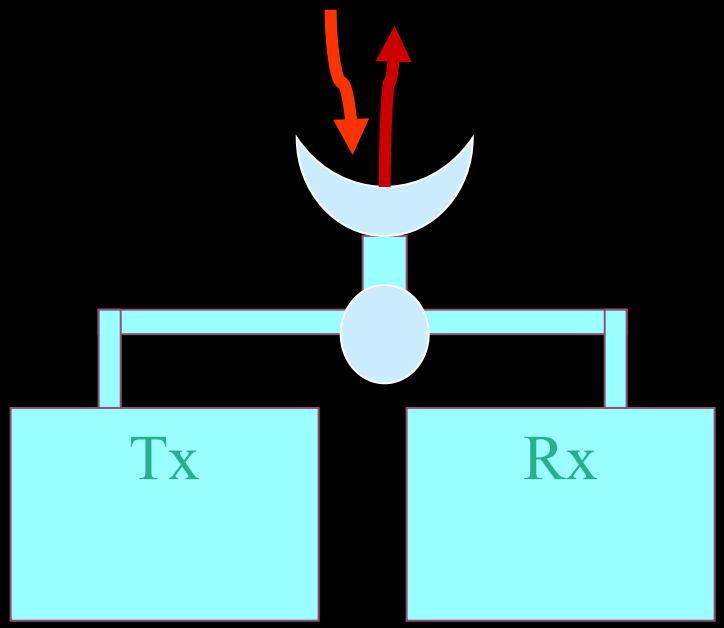


Depth of radiation absorption from a 900 MHz cell phone signal for different age humans: 5 and 10 years' old and an adult. The legend depicts the intensity in Watts per kilogram. (Credit: *Gandhi* et al., 1996).

$$SAR = \frac{d}{dt}\frac{dW}{dm}$$

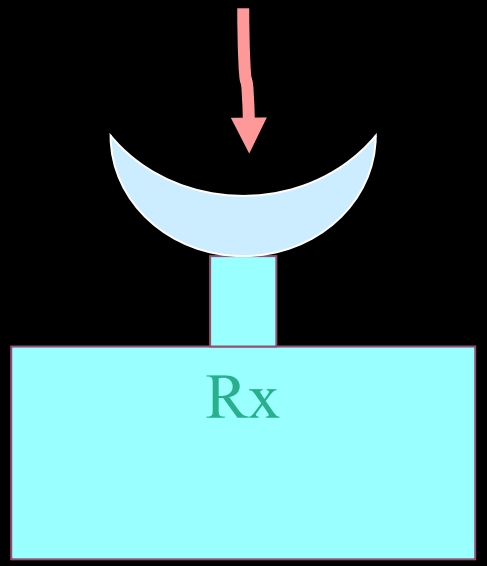
SAR varies by country: in the U.S., the FCC requires certification.

Active and Passive Sensors



Radar

(active sensor)



Radiometer

(passive sensor)

✓Passive radars are NOT passive sensors

RFI = RF interference

Passive

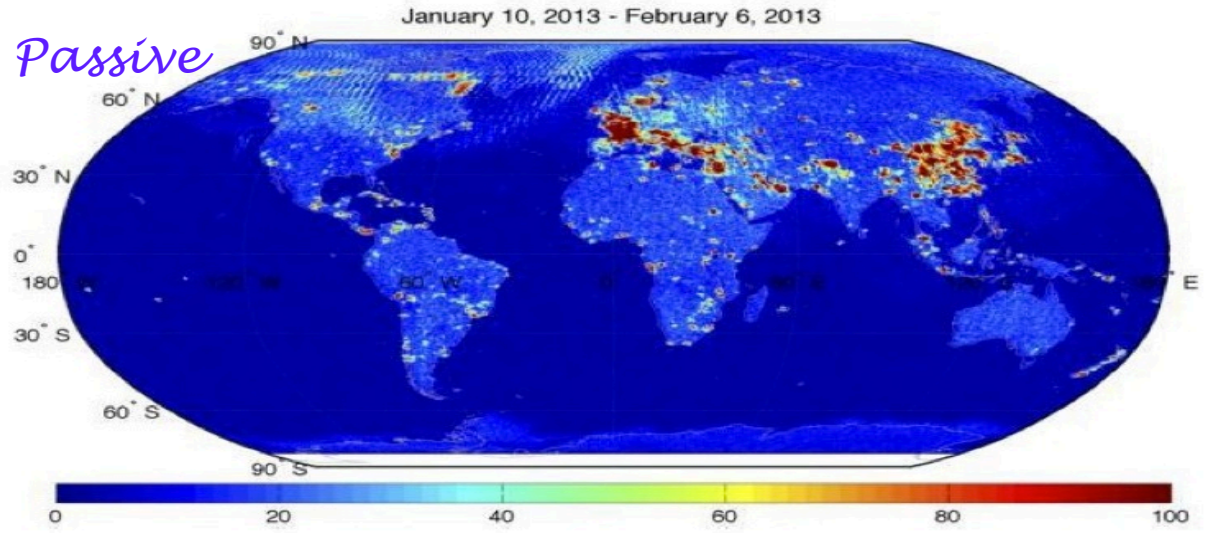


FIGURE 1 Percentage of samples flagged as RFI. This is data from the Aquarius radiometer which operates in the band at 1.413 GHz protected for passive use only (Le Vine et al, IEEE TGARS, 45, 2007). The radiometer observes the earth with a footprint diameter of about 100 km. Each observation is tested for RFI and the map shows the percentage of samples identified as RFI and removed from data processing. The map illustrates the magnitude of the problem even in a band protected for passive use. The map is similar to observations by the SMOS L-band radiometer (Oliva et al, IEEE TGARS, 50, 2012).

Active

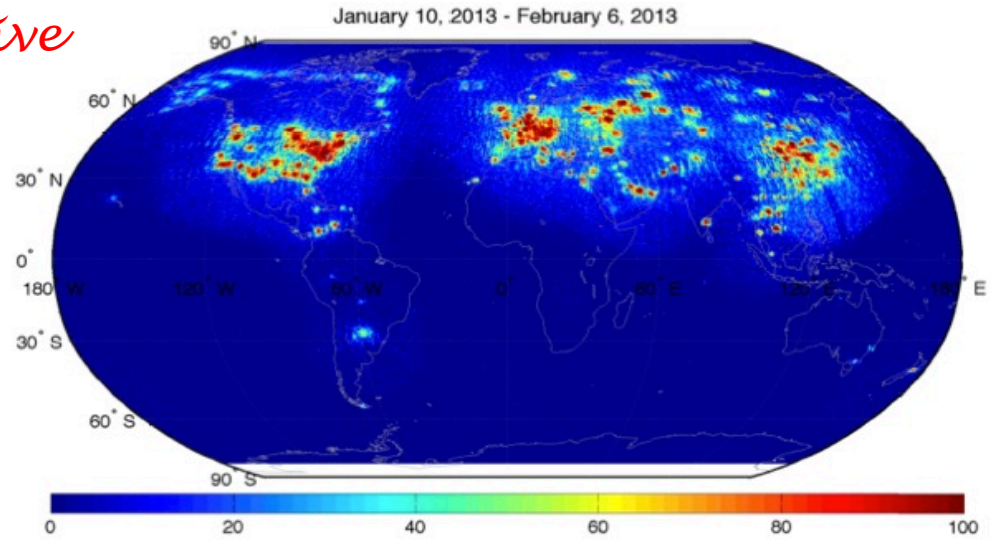


FIGURE 2 The distribution of RFI in the active band as detected by the scatterometer (radar) aboard the Aquarius/SAC-D satellite. The map shows the percentage of radar observations contaminated by RFI. The radar operates in the band 1215-1300 MHz and the figure is an illustration of the potential for RFI problems in the active EESS services. SOURCE: David Le Vine, committee member.

RFSM Definitions

- RFI – Radio-frequency interference
- OOBE =out of band emissions
- Spurious emission: nonintentional emission frequency outside the necessary BW and the level of which may be reduced without affecting TX.
- Harmful interference = degrades the performance of another service

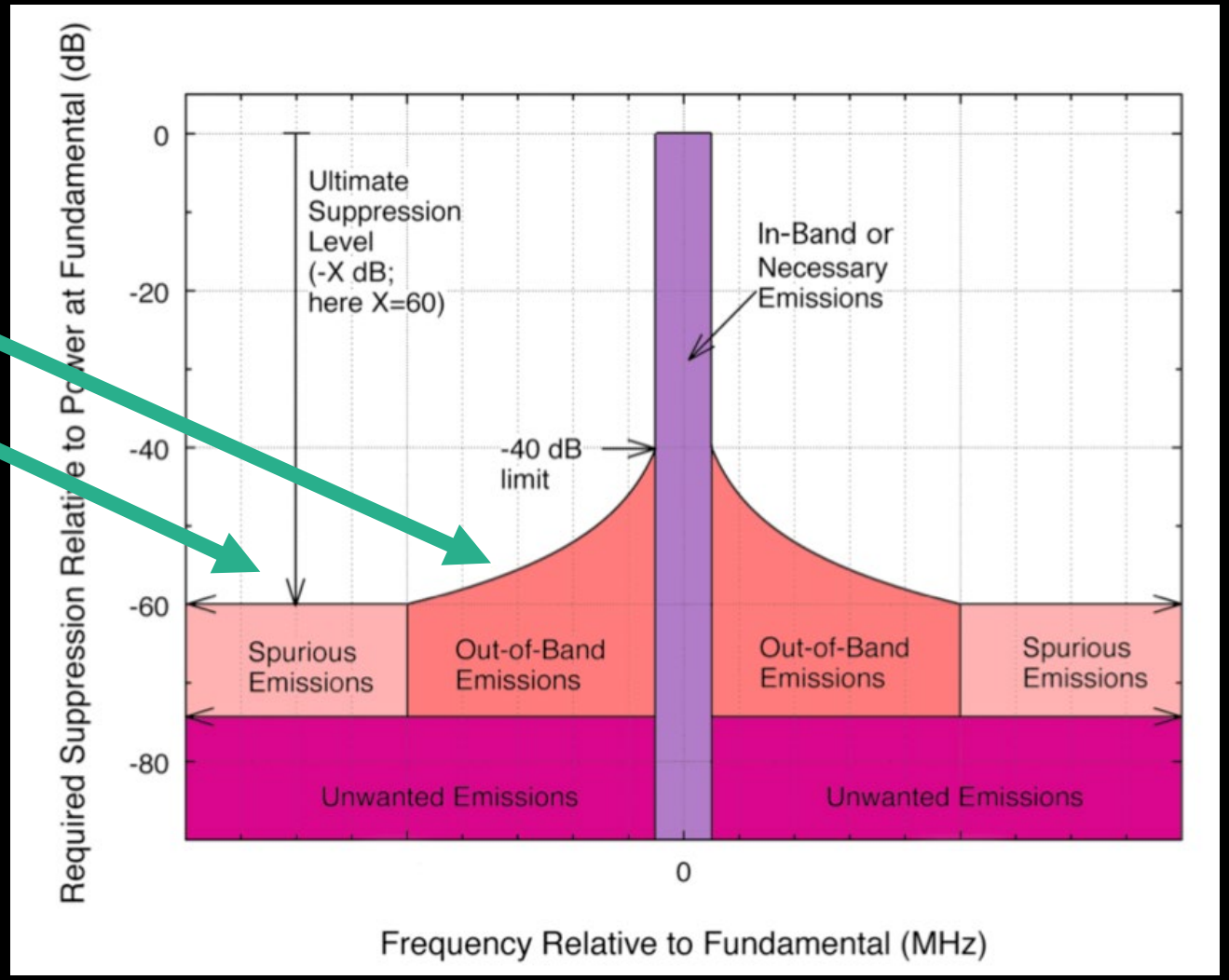
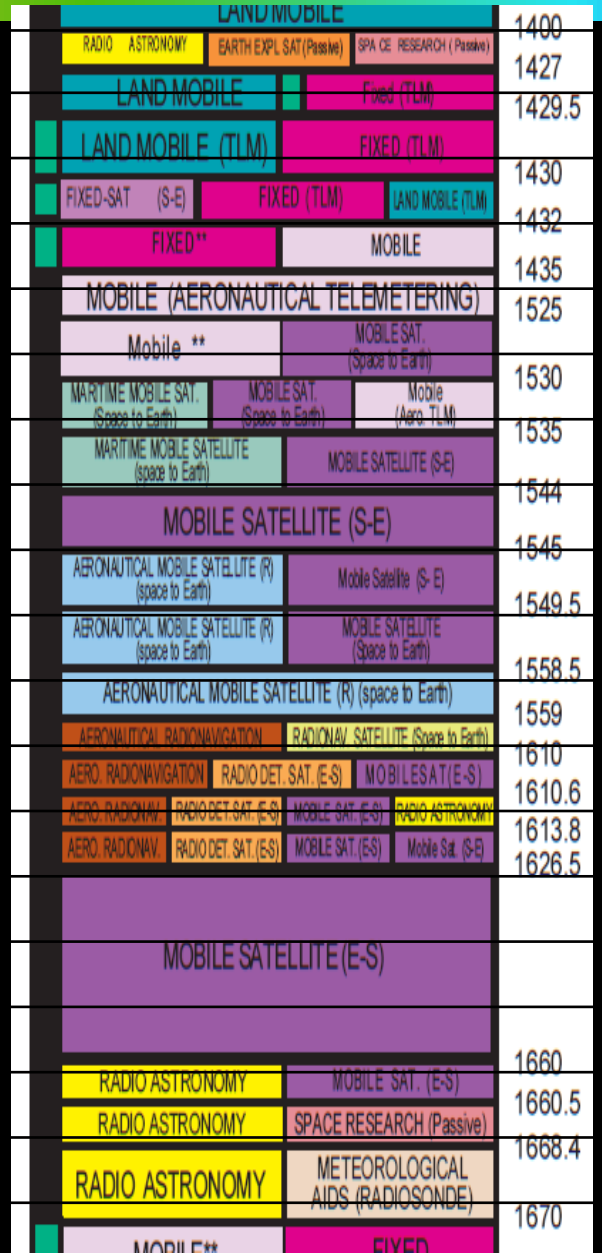


*Image courtesy NTIA via L. Cohen, NRL

List of some RF Services abbreviations

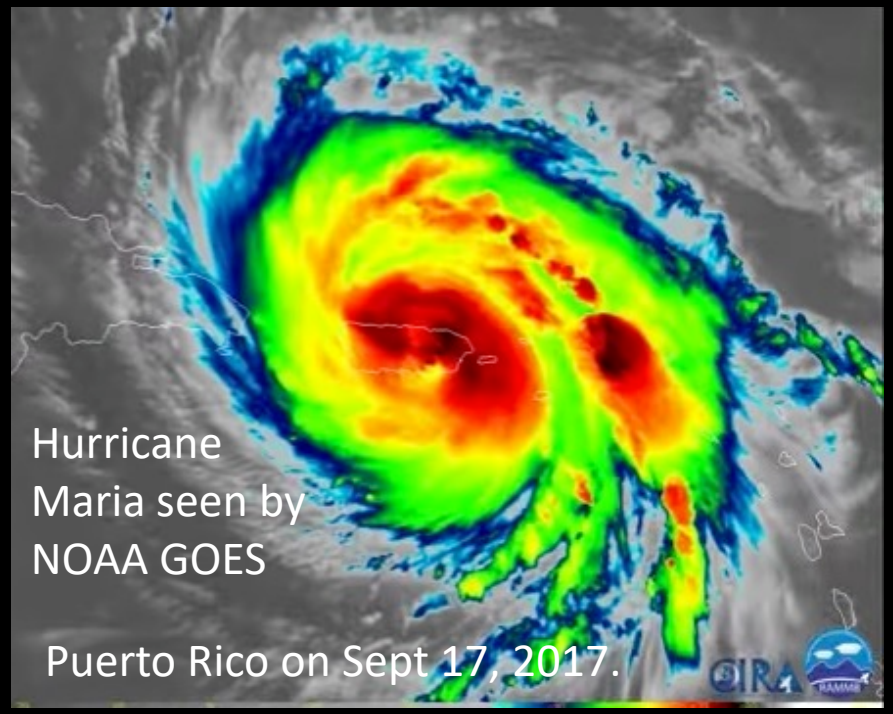
Abbreviations	Radio services
AMS	aeronautical mobile service
AM(R)S	aeronautical mobile (route) service
AMSS	aeronautical mobile-satellite service
AMS(R)S	aeronautical mobile-satellite (route) service
ARNS	aeronautical radionavigation service
ARNSS	aeronautical radionavigation-satellite service
AS	amateur service
ASS	amateur-satellite service
BS	broadcasting service
BSS	broadcasting-satellite service
EESS	Earth exploration-satellite service
FS	fixed service
FSS	fixed-satellite service
ISS	inter-satellite service
LMS	land mobile service
LMSS	land mobile-satellite service
MetAids	meteorological aids service



MetSat

- Meteorological satellite service- refers to weather satellites

WeaaterBug App



RNSS

RadioNavigation Satellite service

- The global navigation satellite system (GNSS) Service, provide accurate position and timing data –GPS

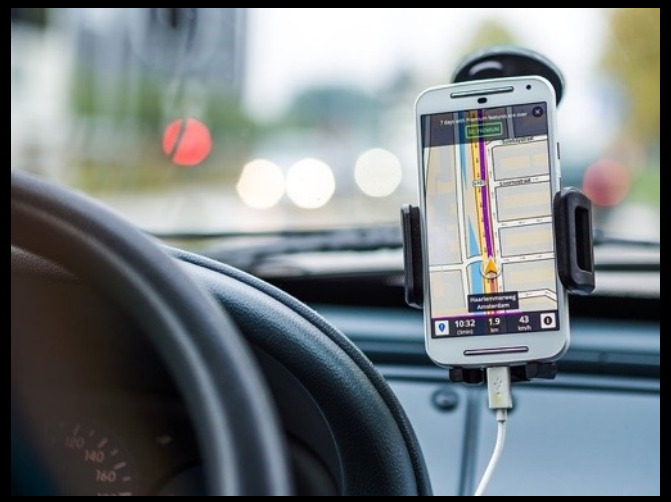
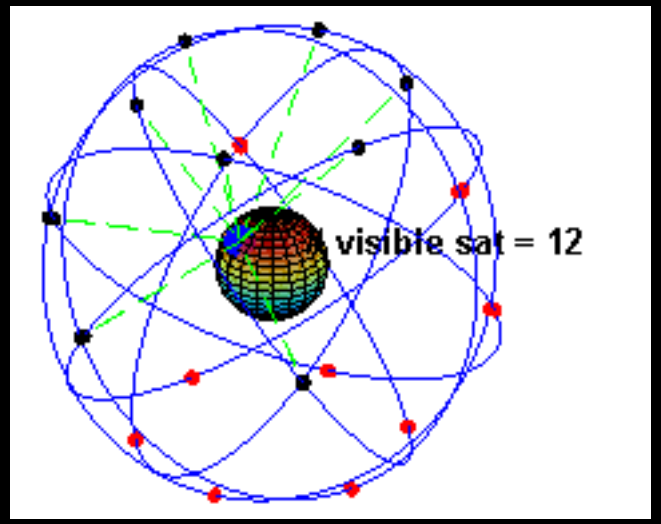


Image by Dariusz Sankowski from Pixabay



EESS

- The Earth Exploration Satellite Service – performs remote sensing from orbit both active and passive and the data downlinks for their satellites

NOAA POES Weather Satellite

RAS

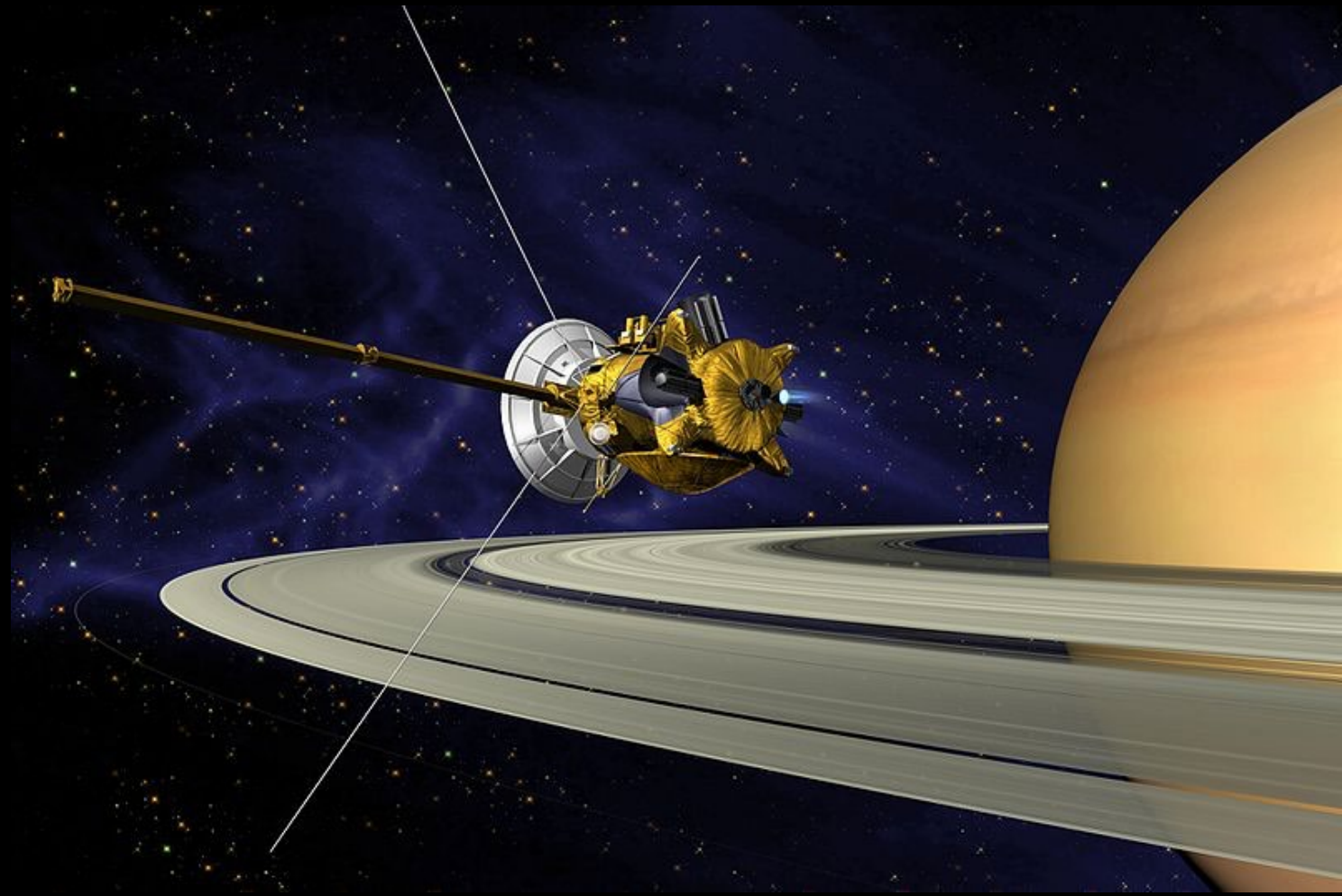
Radio Astronomy Service

uses mostly passive ground-based observations for the reception of radio waves of cosmic origin but also uses satellites to study objects far away in space.

RAS ground-based system: CARMA

SRS

- Space Research Satellite Service –includes near-Earth and deep-space satellites that operate on or around planets and includes telemetry and data downlinks for space RAS and other science satellites.



Cassini spacecraft Credit: NASA

Outline

- Motivation
- Radio Regulations
  - International Level
  - National Level
- Selecting a Frequency
  - NSF Spectrum Managers
- Acronyms & Concepts
- Conclusion

References

FREE

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2. CORF Spectrum Management for the 21st Century, NAS, 2010
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4. NASA Spectrum 101; An Introduction to National Aeronautics and Space Administration Spectrum Management, 2016
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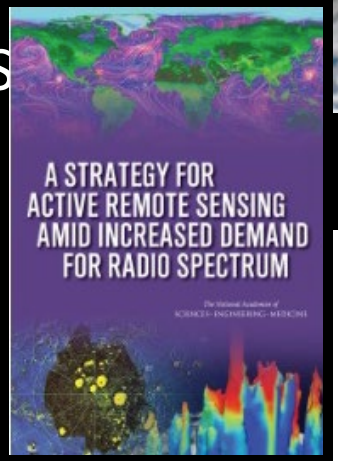

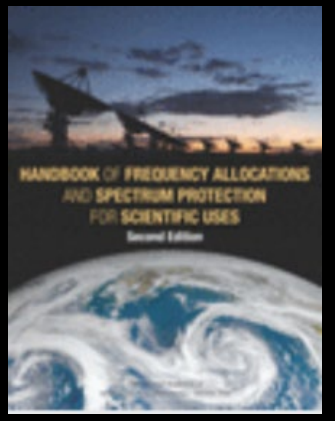

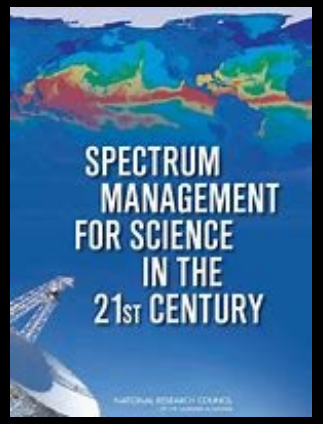

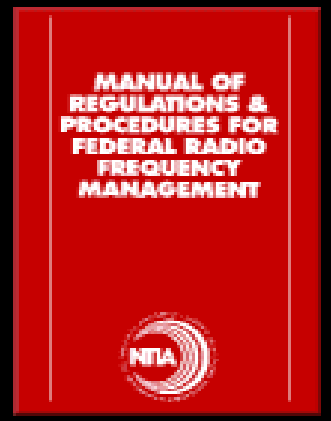

Points to take with you

This has been a brief intro to the RF Spectrum Management and Radio Regulations

Inspires you to learn more about the RR

and to how to select your frequency

For assistance with federal frequency assignments of NSF facilities: contact ESM@nsf.gov

Thank you!

For non-federal frequency licenses contact FCC

For assignments for federal facilities not NSF-funded contact NTIA

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Questions?