

Radio Frequency Spectrum

Management Workshop

Mayaguez, Puerto Rico
May 23 - 27, 2016



to Puerto



Introduction to the RF Spectrum

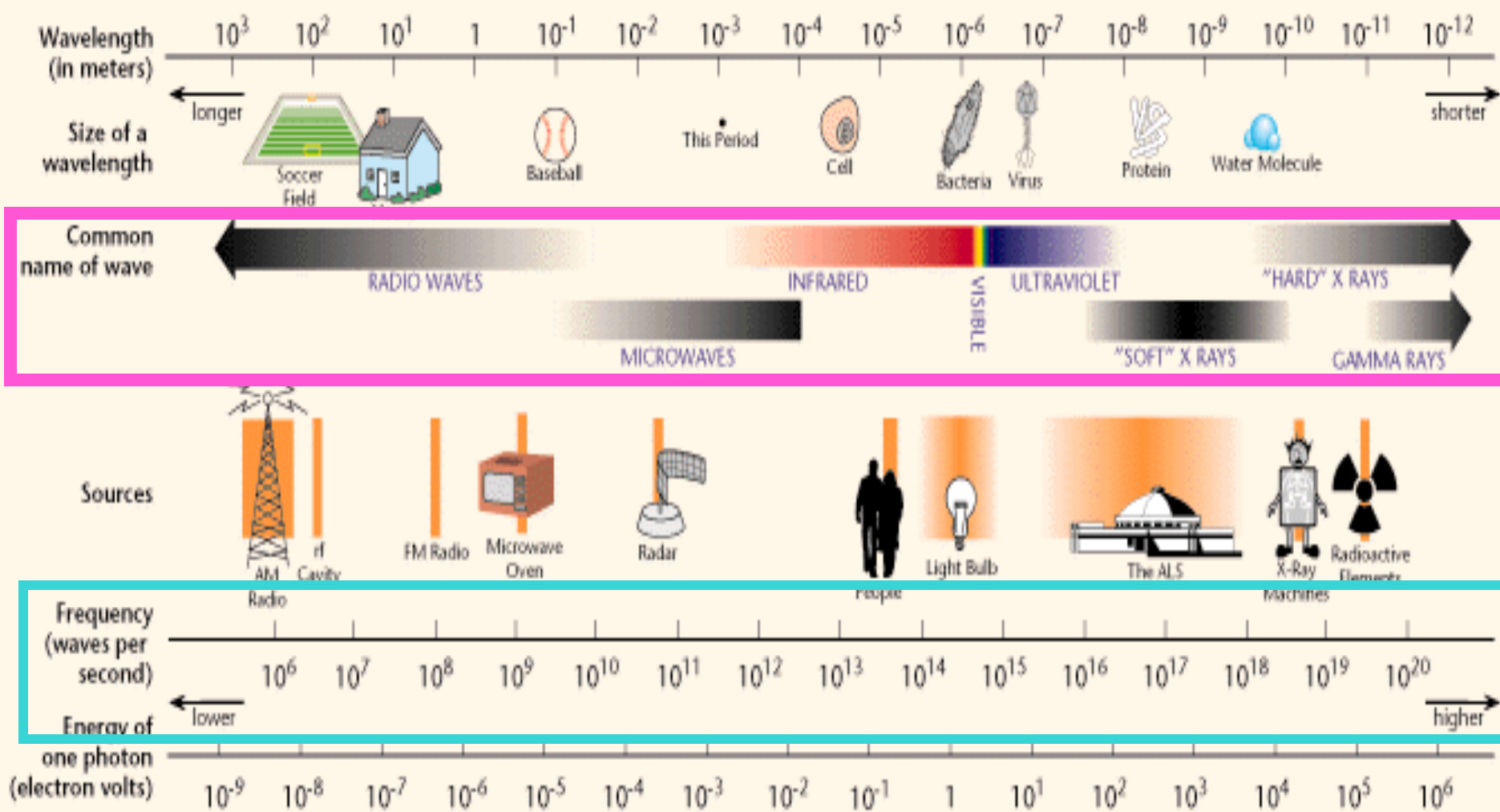
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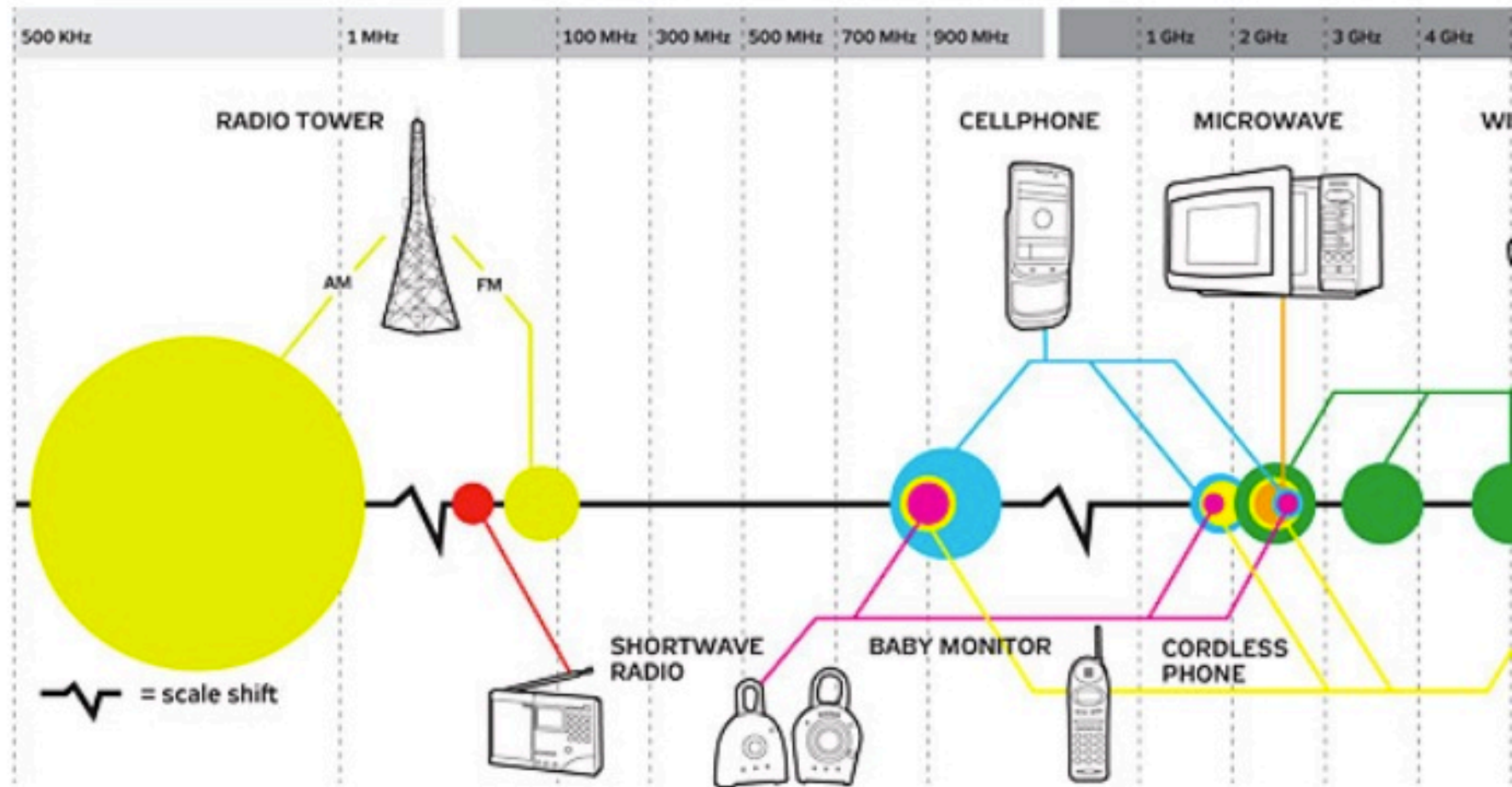
RF Spectrum Management Workshop, UPR-Mayagüez, May 23-27, 2016

THE ELECTROMAGNETIC SPECTRUM



<http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html>

What's My Gadget's Wavelength?



Radio-frequency interference occurs when the signal emitted by one device gets unintentionally picked up by another—creating audible noise or a compromised connection. Some interference is due to unshielded wires or components, but some is just the result of too many gadgets crowded into a small space.

<http://www.popularmechanics.com/technology/how-to/tips/how-to-fight-rf-interference-with-your-gadgets>

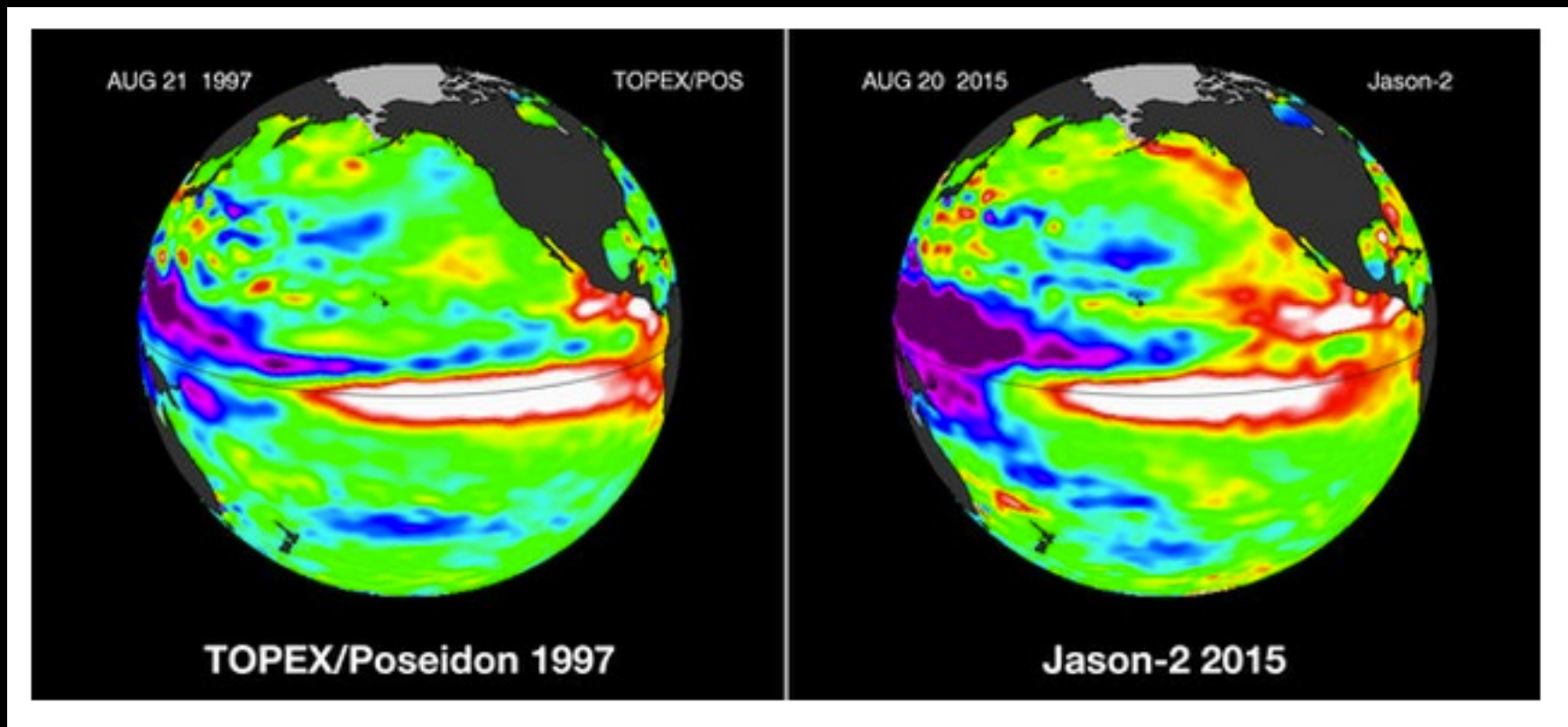
Imagine a World w/o RF

- Airport implications in navigation
- Solar storms not predicted
 - (Energy grid disruption)
- No GPS
- EESS no data on hurricane tracks,
 - No El Niño forecast
- No cellphones! Satellite TV, Wi-Fi internet, AM and FM radio, broadcast TV , satellite TV



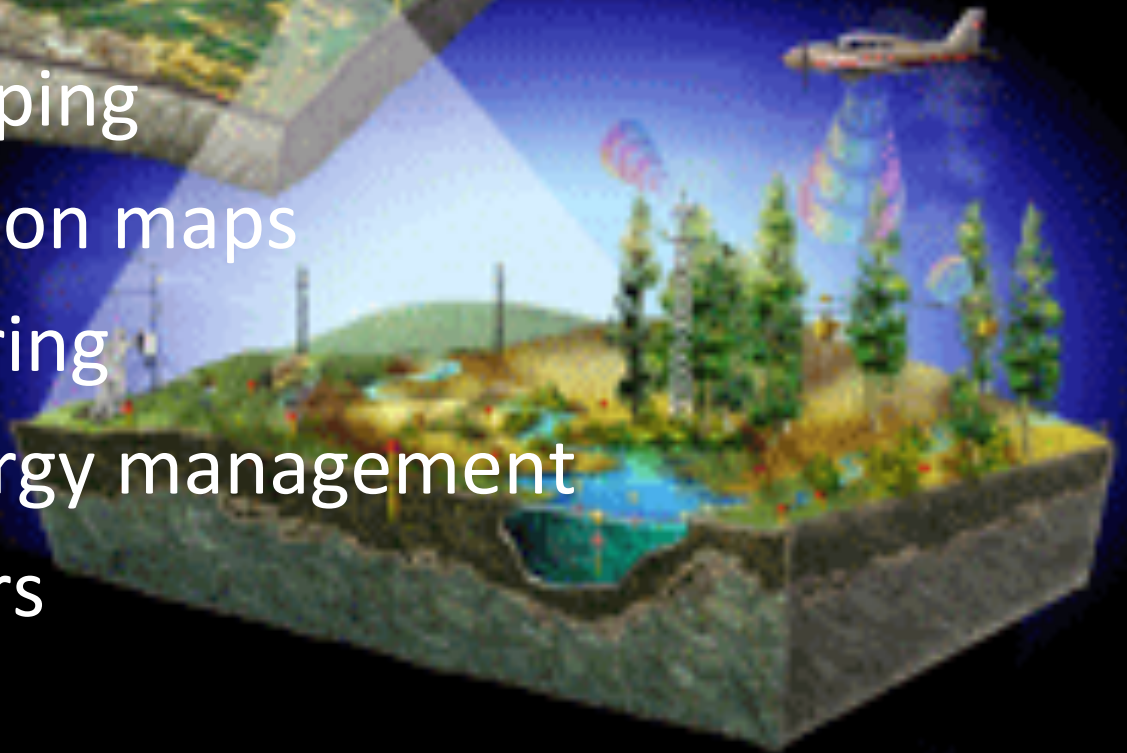
El Niño/ La Niña

<https://sealevel.jpl.nasa.gov/>



Some Applications

- Agriculture
- Fire-prone mapping
- Iceberg navigation maps
- Oil spill monitoring
- Renewable energy management
- Vacuum cleaners
- Baby monitors



RF Spectrum definition

- It's the range of frequencies of *em* waves
Between 3kHz-3THz



How do we choose f ?

Many factors: like antenna size, available technology, cost,.. but mainly:

- Atmospheric attenuation
- Physical properties of EM waves vary with frequency
 - Resonant molecules,
 - Sensitivity to Earth parameters,

Atmospheric Attenuation

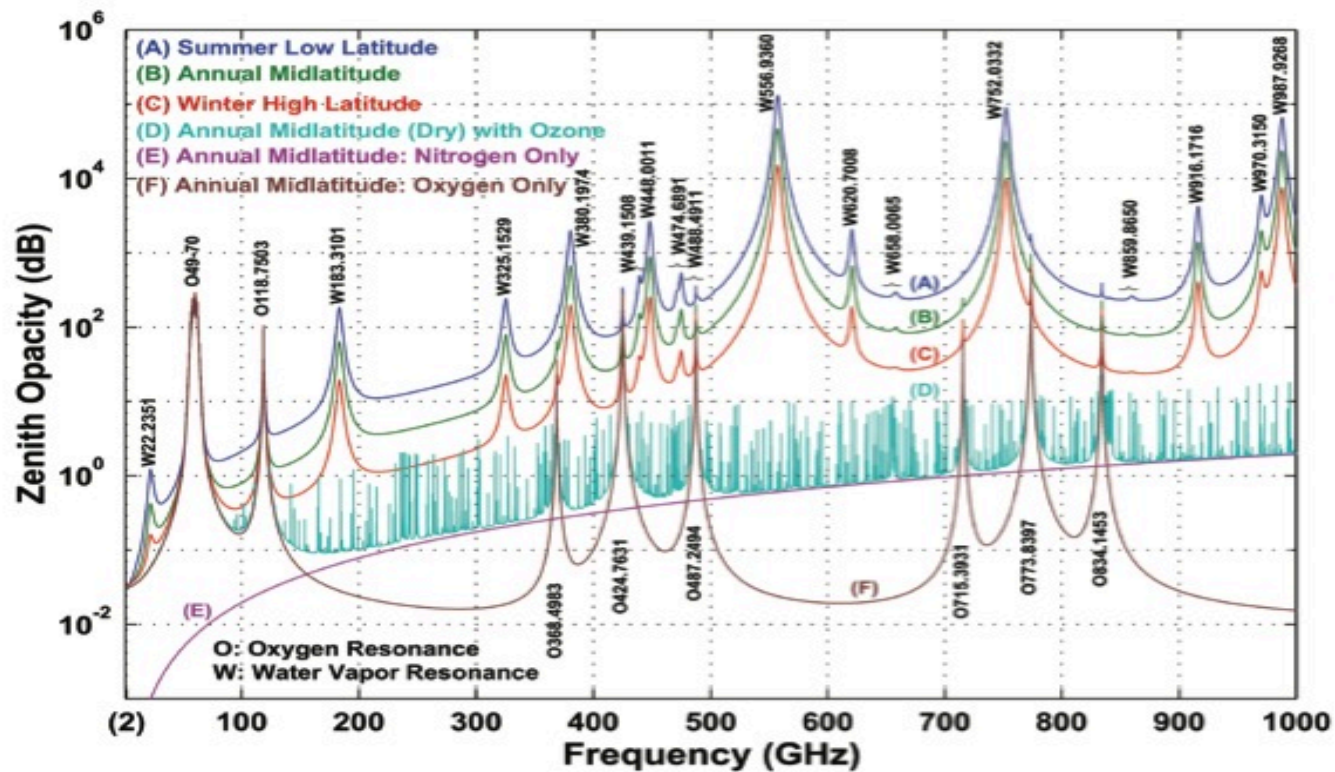


FIGURE 1.2 The opacity of Earth's atmosphere in the radio range of frequencies from 1 to 1000 GHz for six scenarios. Image courtesy of A.J. Gasiewski, University of Colorado.

Due to resonance with several molecules

Atmospheric Transmissivity

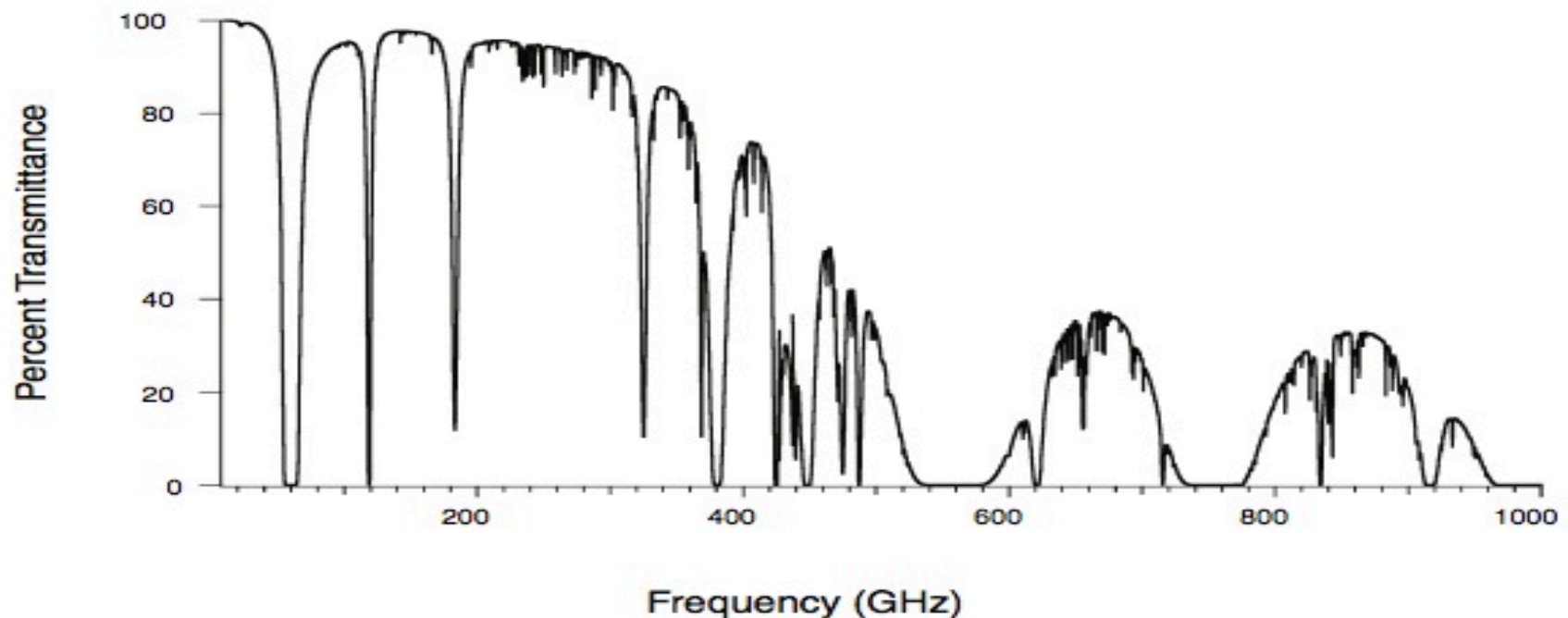
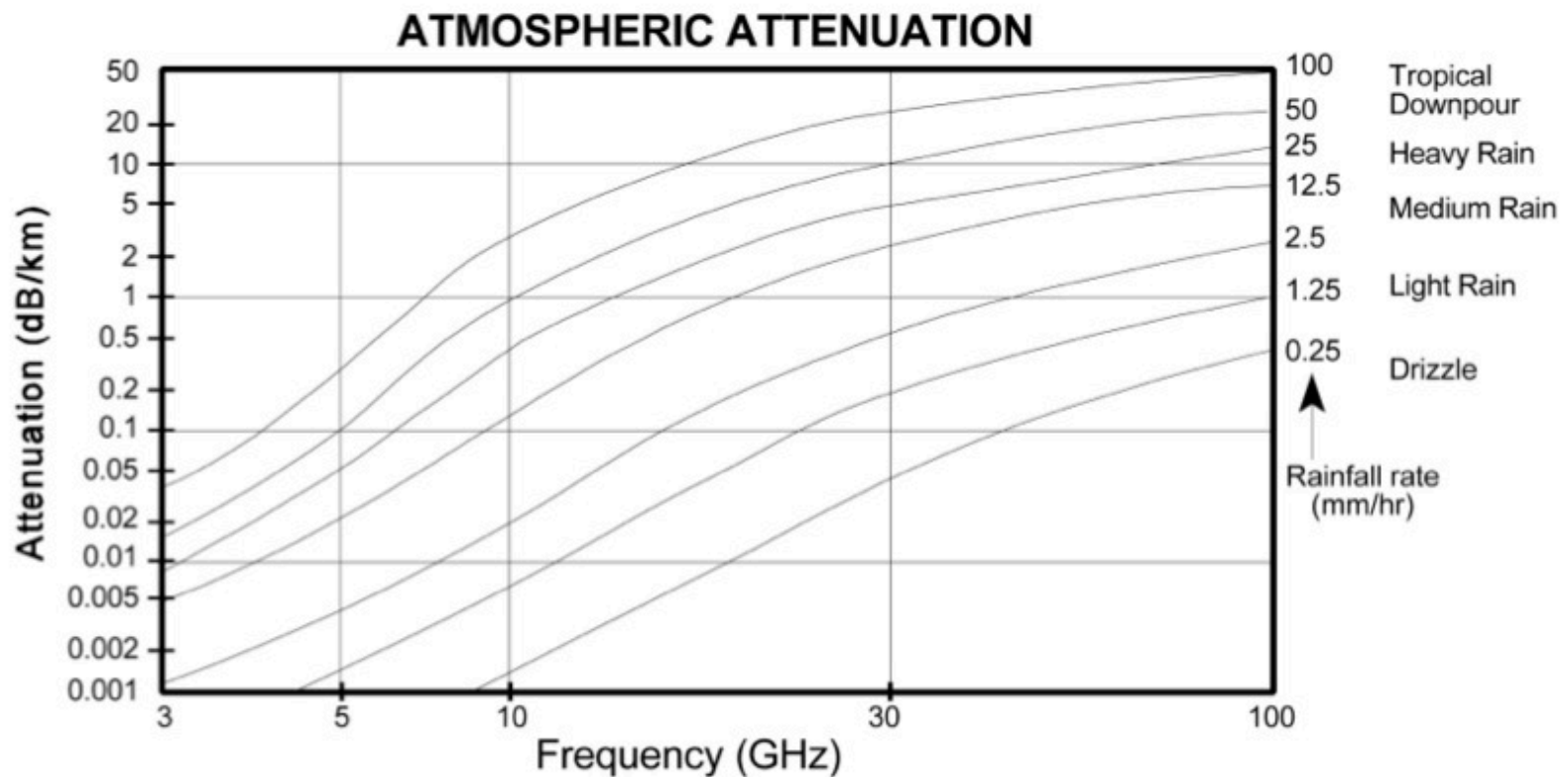


FIGURE 1.3 The transmission spectrum of Earth's atmosphere in the radio range of frequencies from 1 to 1000 GHz at Mauna Kea, Hawaii, a very dry site at an altitude of approximately 14,000 ft. Such

In general, attenuation increases as frequency increases .
Price also increases but antenna size is smaller.

Atmospheric Attenuation (Rain)



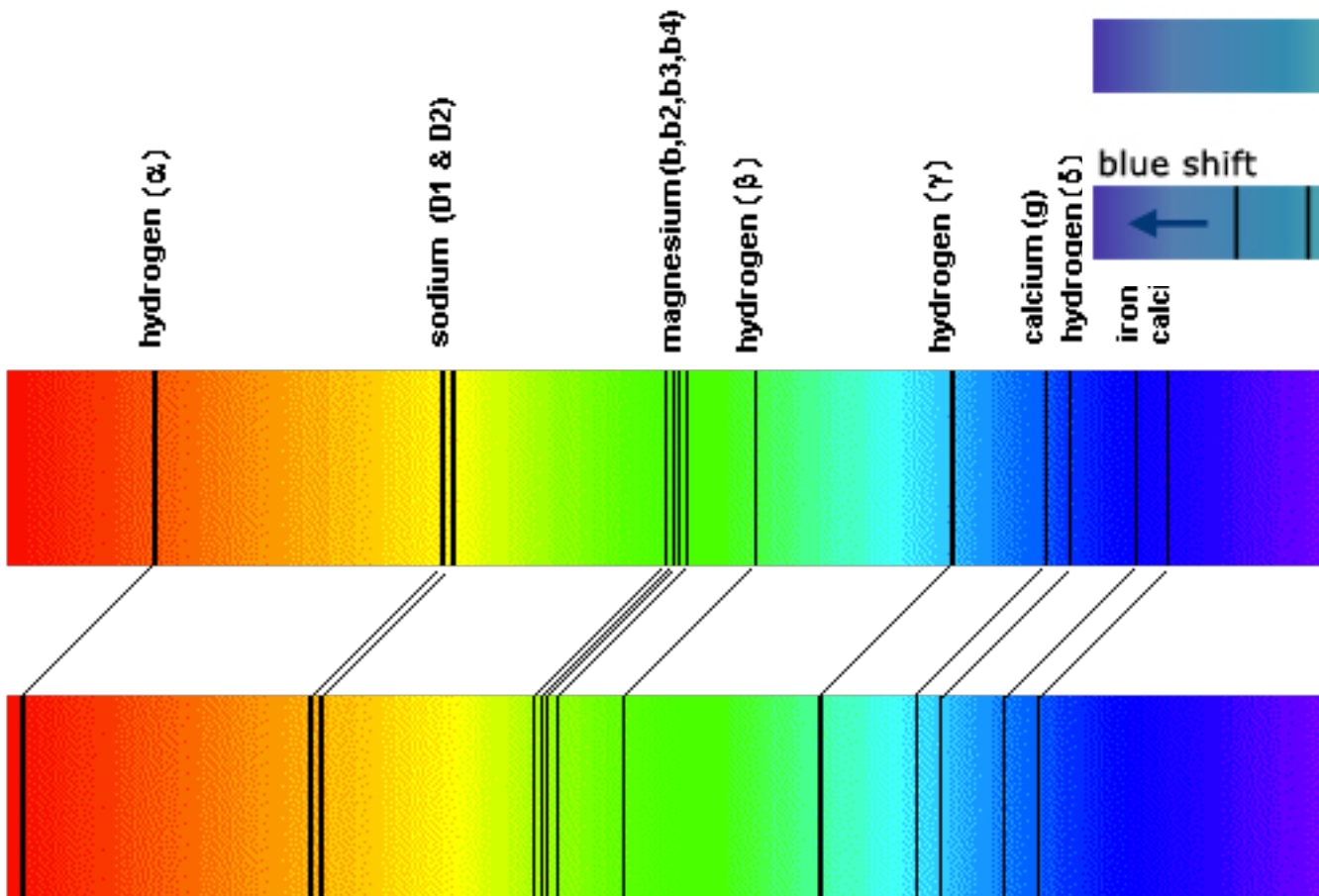
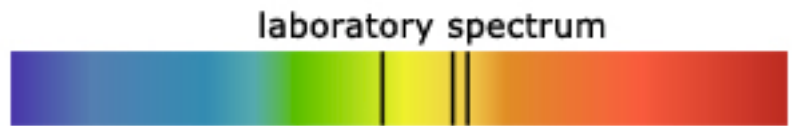
Effect of weather conditions on atmospheric attenuation

Many other factors affect the propagation of em waves: diffraction, scattering...

Astronomical Spectral Lines and Continuum

Needed to study **quasars**, **black holes**, **CMB** (Big Bang), dark matter, planets...

Doppler Shift



Sensitivity

$$\Delta T = \frac{1}{\sqrt{\tau \cdot BW}}$$

in some cases we can increase integration time, τ or increase the bandwidth

Red shifting causes all the bands to be shifted the same amount so each band can still be identified and the amount of red shift measured.

How do we choose f ?

Depends on what we are observing

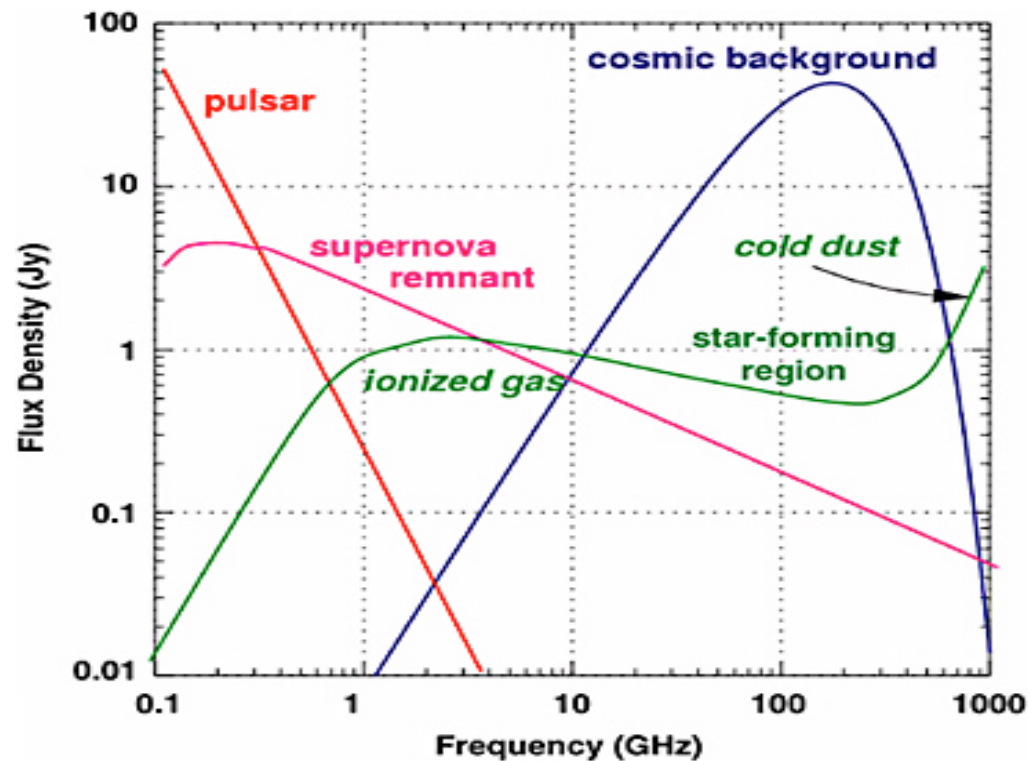


FIGURE 2.2 Spectra of typical continuum radio sources. The flux levels shown correspond to the strongest known sources. A jansky (Jy) is $10^{-26} \text{ W m}^{-2} \text{ Hz}^{-1}$.

Sensitivity of f

- The physical parameters we want to measure, need to use specific frequency,

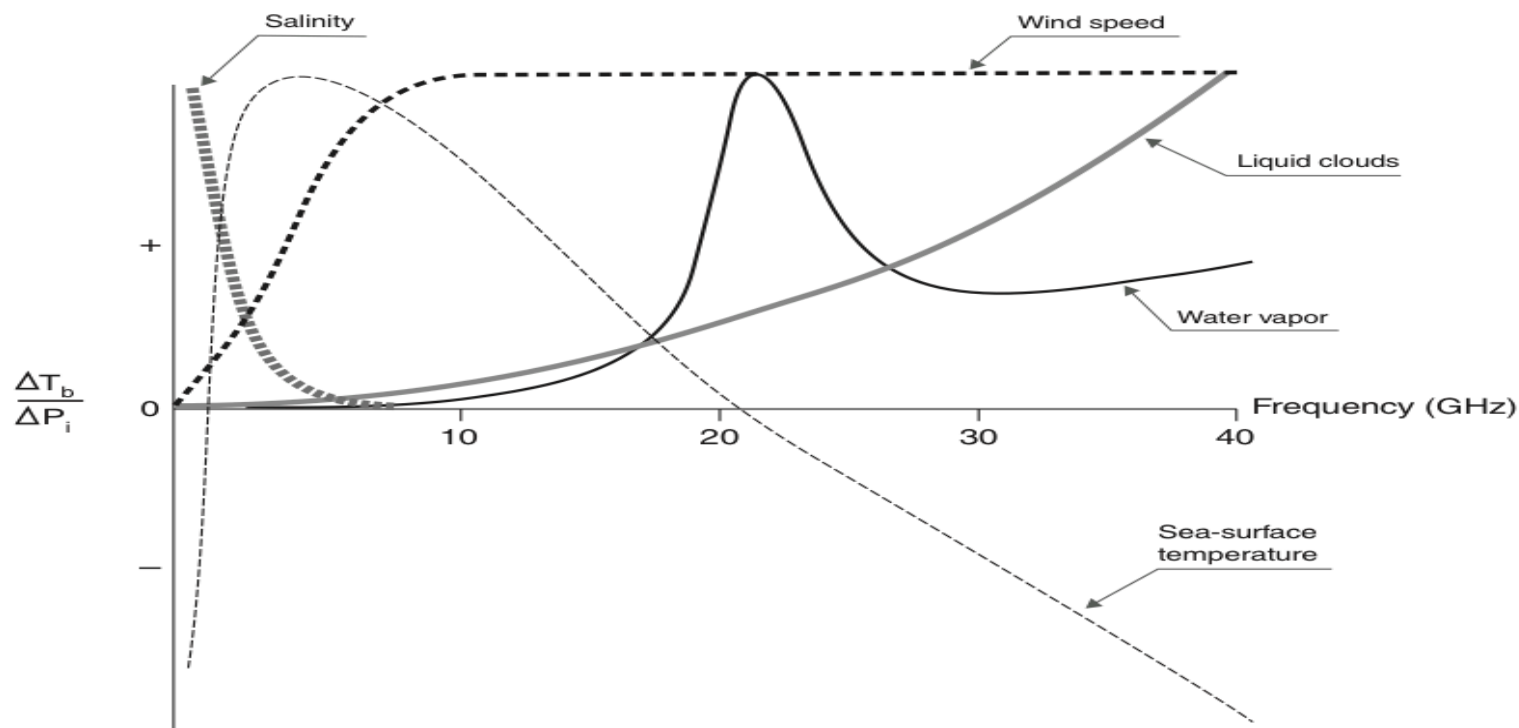


FIGURE 2.11 Ocean scene: relative sensitivity of sea surface salinity, sea surface temperature, cloud liquid water, and integrated water vapor as a function of frequency for space-based measurements. Original figure by Thomas T. Wilheit, NASA-GSFC.

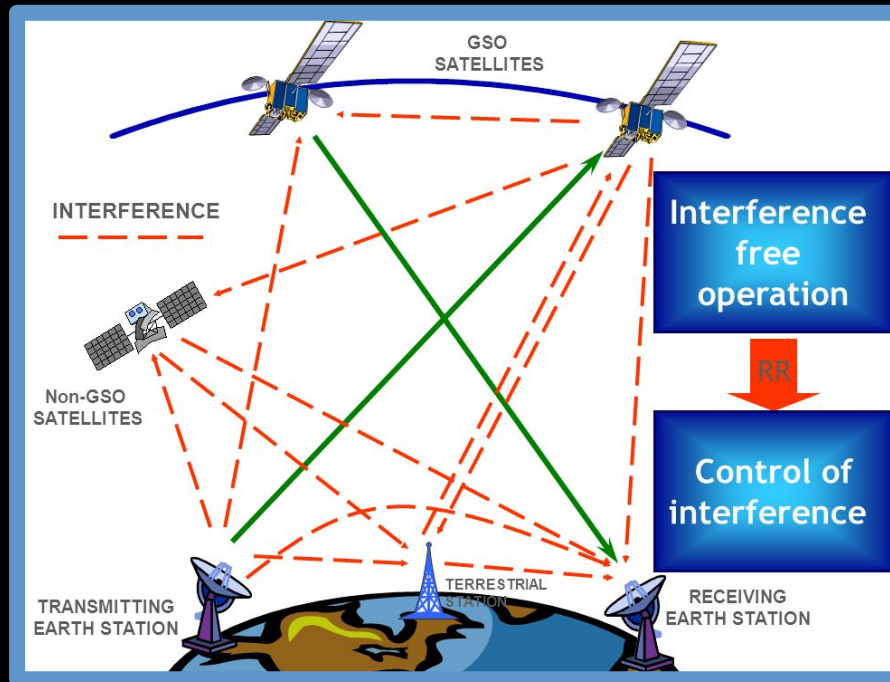
Passive surviving in an Active world

Active

- Tx & Rx

Passive-

- only Rx



RFI

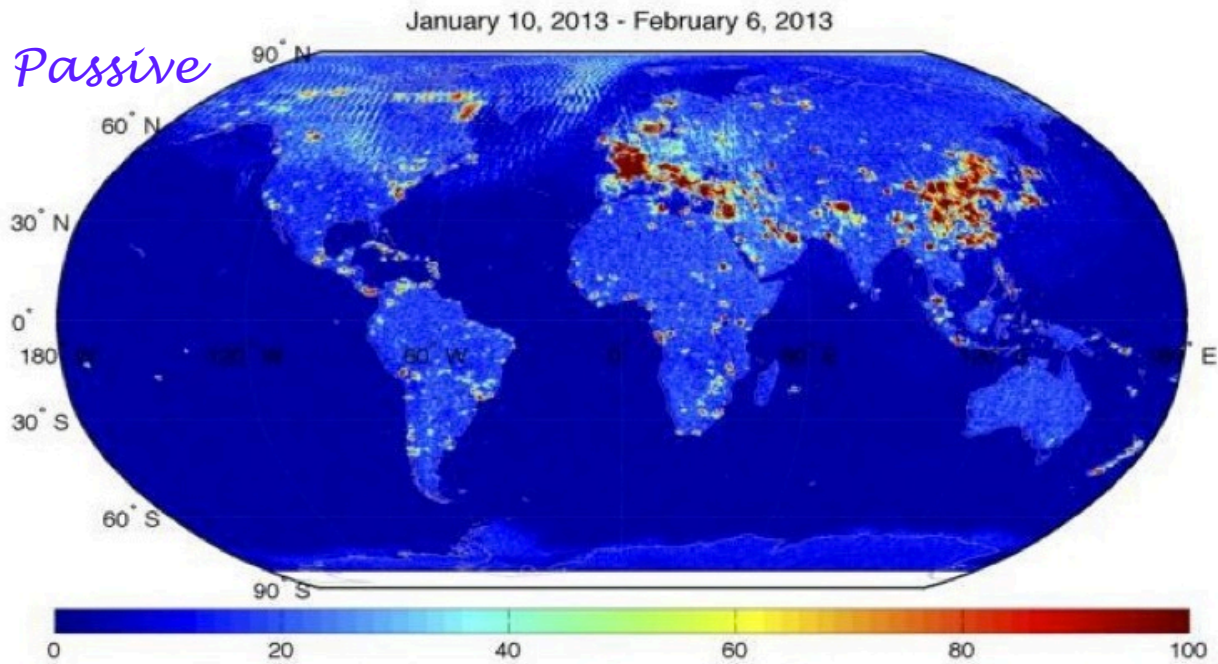


FIGURE 1 Percentage of samples flagged as RFI. This is data from the Aquarius radiometer which operates in the band at 1.413 GHz protected for passive use only (Le Vine et al, IEEE TGARS, 45, 2007). The radiometer observes the earth with a footprint diameter of about 100 km. Each observation is tested 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 (Le Vine et al, IEEE TGARS, 45, 2007).

Active

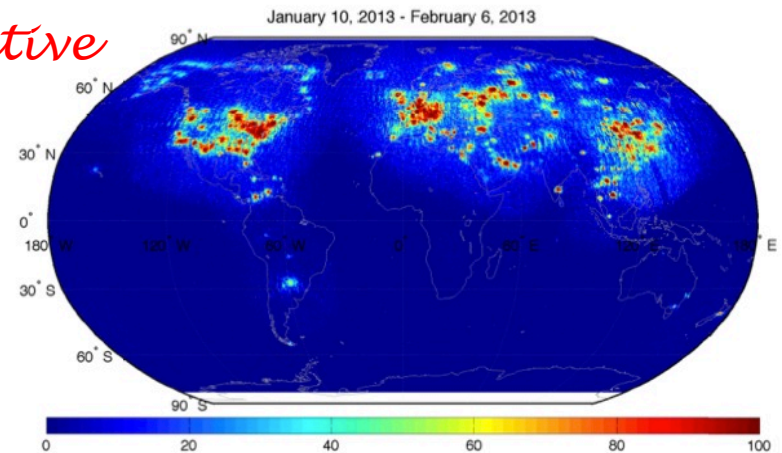


FIGURE 2 The distribution of RFI in the active band as detected by the scatterometer (radar) aboard the Aquarius/SAC-D satellite. The map shows the percentage of radar observations contaminated by RFI. The radar operates in the band 1215-1300 MHz and the figure is an illustration of the potential for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

NASA SMAP

- Launched Jan 2015
- Less than 2 month of data
- Unable to 'see' due to RFI

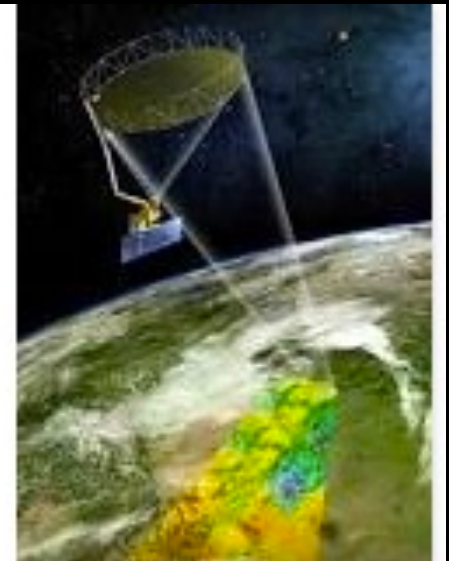
Soil Moisture Active Passive

Satellite

Soil Moisture Active Passive is an American environmental research satellite launched on 31 January 2015. It is one of the first Earth observation satellites being developed by NASA in response to the National Research Council's Decadal Survey. [Wikipedia](#)

Launch date: January 31, 2015

Operator: [NASA](#)



SPACEFLIGHT NOW

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September 21, 2015 in News: China aims for landing on moon's far side by 20:

Radar on NASA's SMAP Earth observing satellite declared lost

Posted on September 3, 2015 by Stephen Clark

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RFI?



Artist's concept of the SMAP spacecraft and its rotating antenna. Credit: NASA/JPL-Caltech

One-half of the instrument payload aboard NASA's \$916 million Soil Moisture Active Passive satellite has failed after collecting just two months of data, NASA announced Wednesday after weeks of troubleshooting turned up no progress in recovering the sensor.

A radiometer instrument on the SMAP satellite continues functioning as designed, returning coarser maps of how much moisture is absorbed into topsoil than possible with the more sensitive radar, officials said.

But the radar was a big part of what set the SMAP mission, led by NASA's Jet Propulsion Laboratory, apart from other existing satellites with the ability to measure soil moisture on a global scale. Such data is important to scientists who study what drives Earth's water cycle and climate, and it has tangible benefits for farmers and forecasters who worry over droughts and

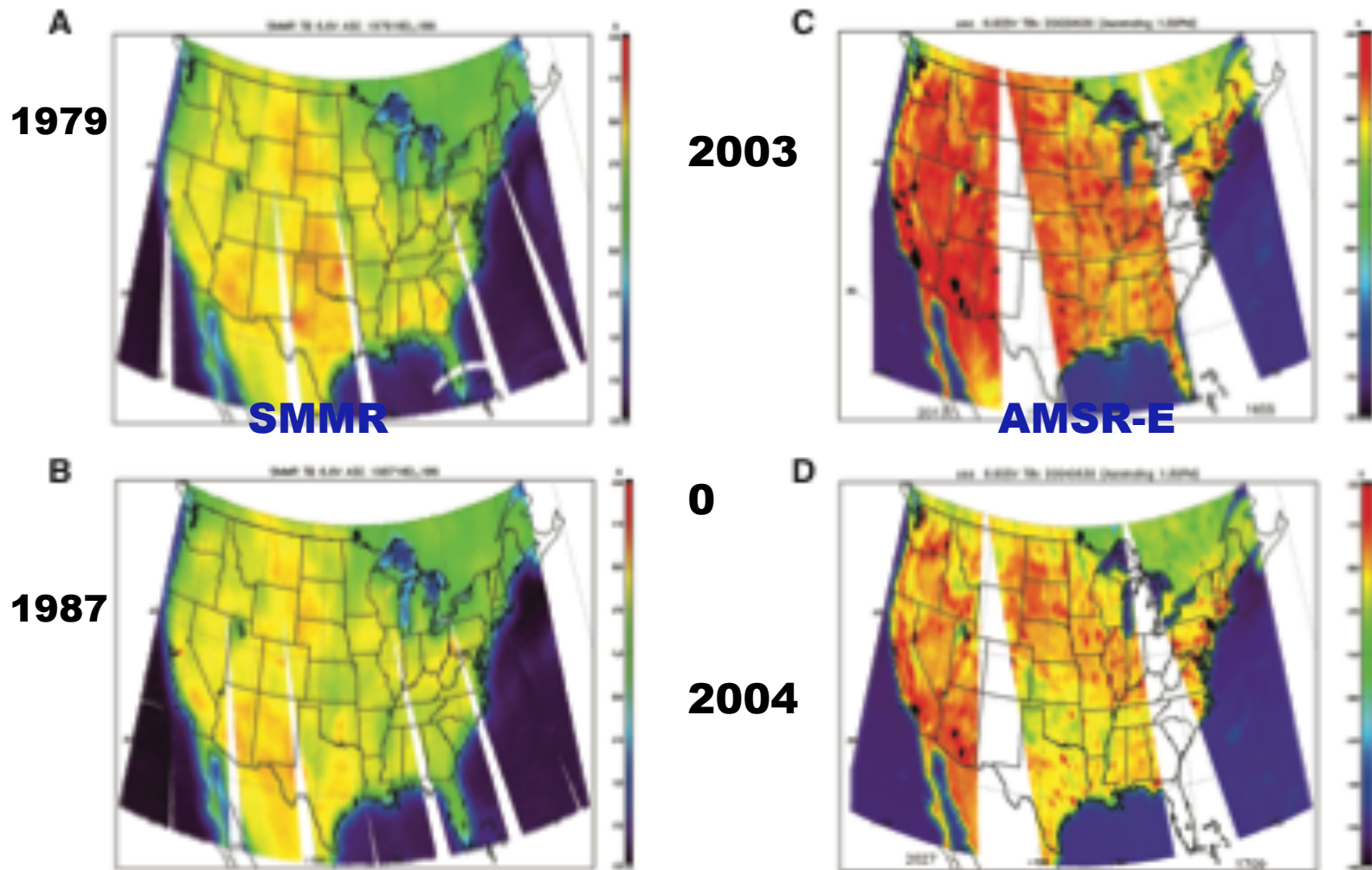
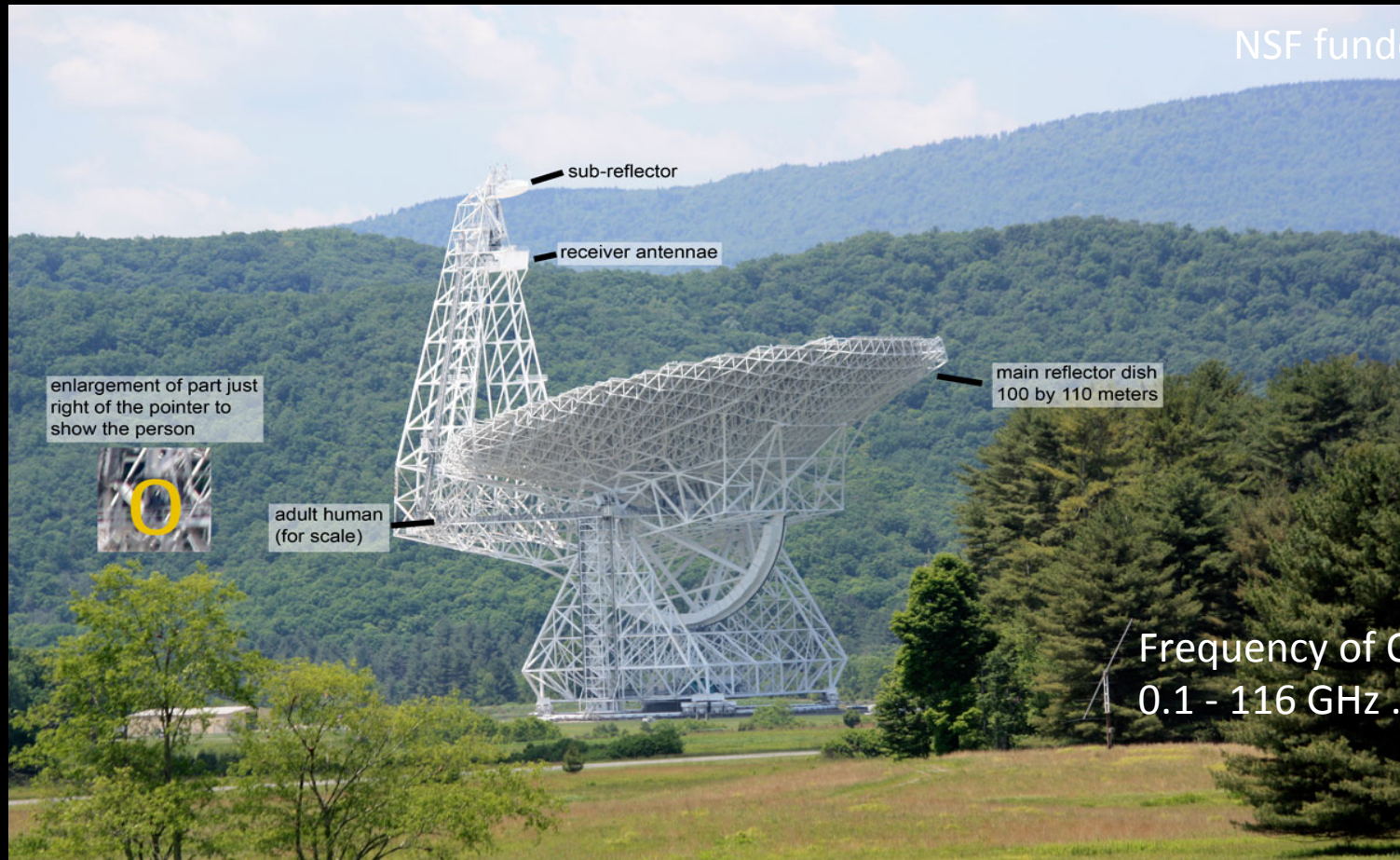


FIGURE 2.22 An example of interference to EESS observations of opportunity at 6.6 GHz. Passive microwave imagery at 6.6 GHz from the Scanning Multi-channel Microwave Radiometer (SMMR) from (A) 1979 and (B) 1987, showing no noticeable brightness temperature from radio frequency interference (RFI). In contrast, passive microwave imagery from the Advanced Microwave Scanning Radiometer-Earth (AMSR-E) on NASA Earth Observing System Aqua from 2003 (C) and 2004 (D) shows substantial RFI. The black spots represent high levels of anthropogenic emission that saturate the AMSR-E radiometer, primarily over regions of California and Arizona. The red spots over most of the remaining areas of the United States represent contaminated brightness-temperature measurements. AMSR-E

Most vulnerable to RFI



Frequency of Operation
0.1 - 116 GHz .

The National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia, operates the world astronomical telescope operating from centimeter to millimeter wavelengths.

The Observatory has an active engineering research and development program ranging in areas from digital, mechanical, structural, computational, and software engineering.

Most vulnerable to RFI



NSF funded facility

Up to 720GHz
in Chile.

ALMA (Atacama Large Millimeter / submillimeter Array) is the largest radio telescope in the world. It was officially put into operation on 13 March 2013 scientific observations take place, however since October 2011. In June 2014 was erected the last of 66 planned antennas. They are used as interferometer for millimeter-wave and submillimeter used. Measures noise-like signals from galaxies far away...

Arecibo Observatory

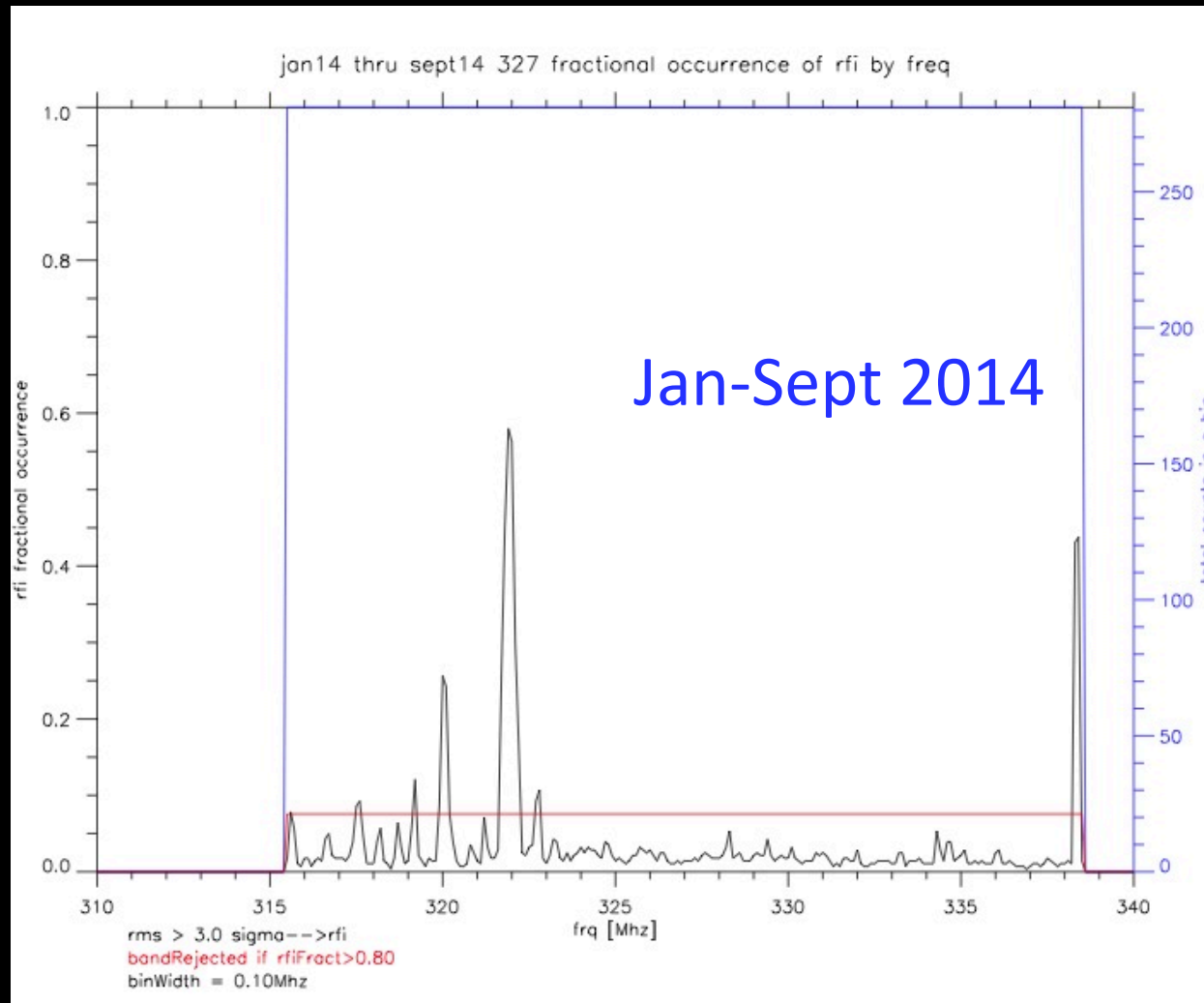
NSF funded facility

Frequencies-
13.36MHz-10.6GHz

Rx Sensitivity=
-250 dBW/m²/Hz



Occurrence of RFI versus frequency by month for Arecibo

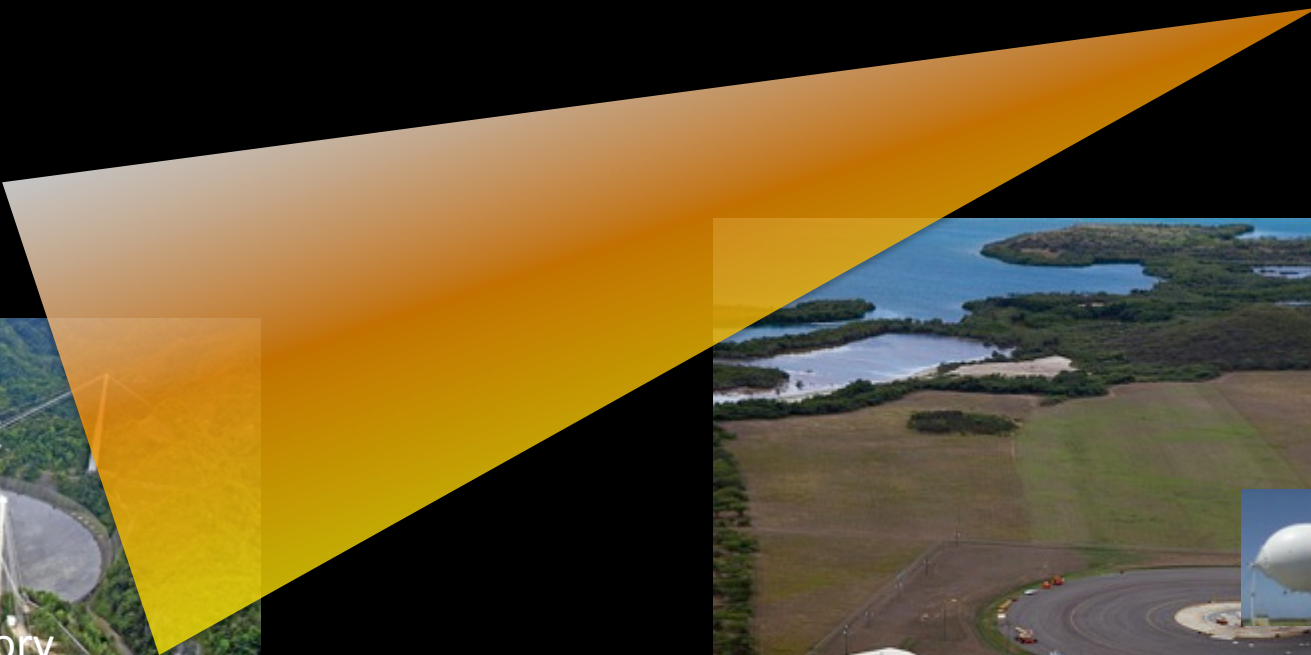
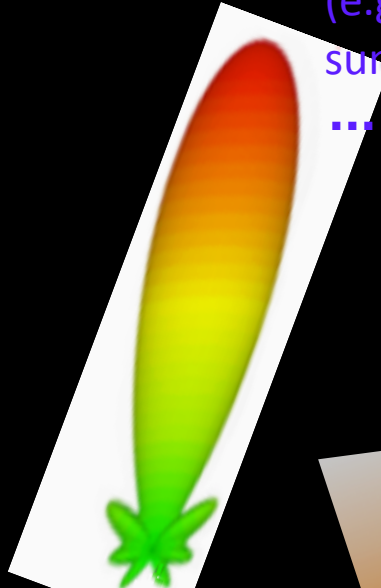


<http://www.naic.edu/~phil/rfi/rms.html>

MOU -Coordination



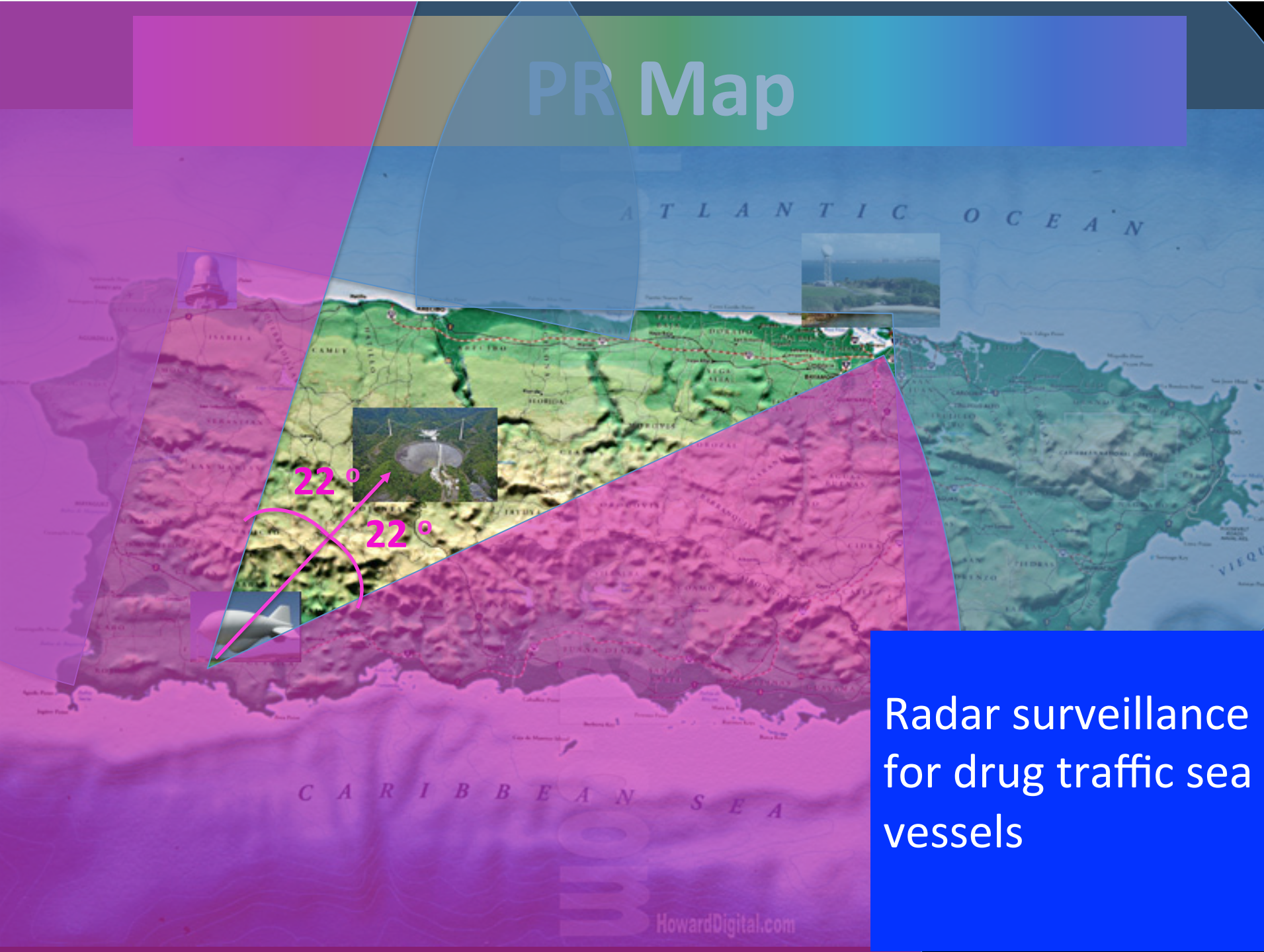
Objects under Study
(e.g. Pulsars,
sunspots, galaxy)
...far, far Away



Passive sensor Rx
(Radiometer)
Arecibo Observatory



PR Map



Radar surveillance
for drug traffic sea
vessels

Arecibo Observatory



http://www.naic.edu/~rfiuser/rfi_id.htm

Photo: Israel Cabrera

I Cabrera



Search



Take Action

Home / The FCC / FCC Encyclopedia / Weather Radar Interference Enforcement

Weather Radar Interference Enforcement

- In this Forfeiture Order (Order), we issue a monetary forfeiture in the amount of twenty-five thousand dollars (\$25,000) to AT&T, Inc. dba AT&T Mobility (AT&T) for willful and repeated violation of Sections 301 and 302(b) of the Communications Act of 1934, as amended (Act), and Sections 15.1(b) and 15.1(c) of the Commission's rules (Rules). The noted violation involves AT&T's operation of an intentional radiator without a license and contrary to the requirements of Part 15 of the Rules and the device's Equipment Authorization.

In addition, on July 27, 2010, the Enforcement Bureau and the Office of Engineering and Technology issued a memorandum providing guidance to manufacturers and operators of U-NII devices.

Enforcement Advisory - Wireless Internet Service Provider Guidance

<http://www.fcc.gov/encyclopedia/weather-radar-interference-enforcement>

Enforcement Actions

10-01-2014	CMARR, Inc., San Juan, PR	FORFEITURE ORDER
06-24-2014	CMARR, Inc., San Juan, PR	NAL
02-21-2014	AT&T Mobility, LLC, Denver, Colorado	FORFEITURE ORDER

You can get \$25,000 fine from FCC if you are using an illegal frequency.

Click to see examples

News from
May 4th 2015

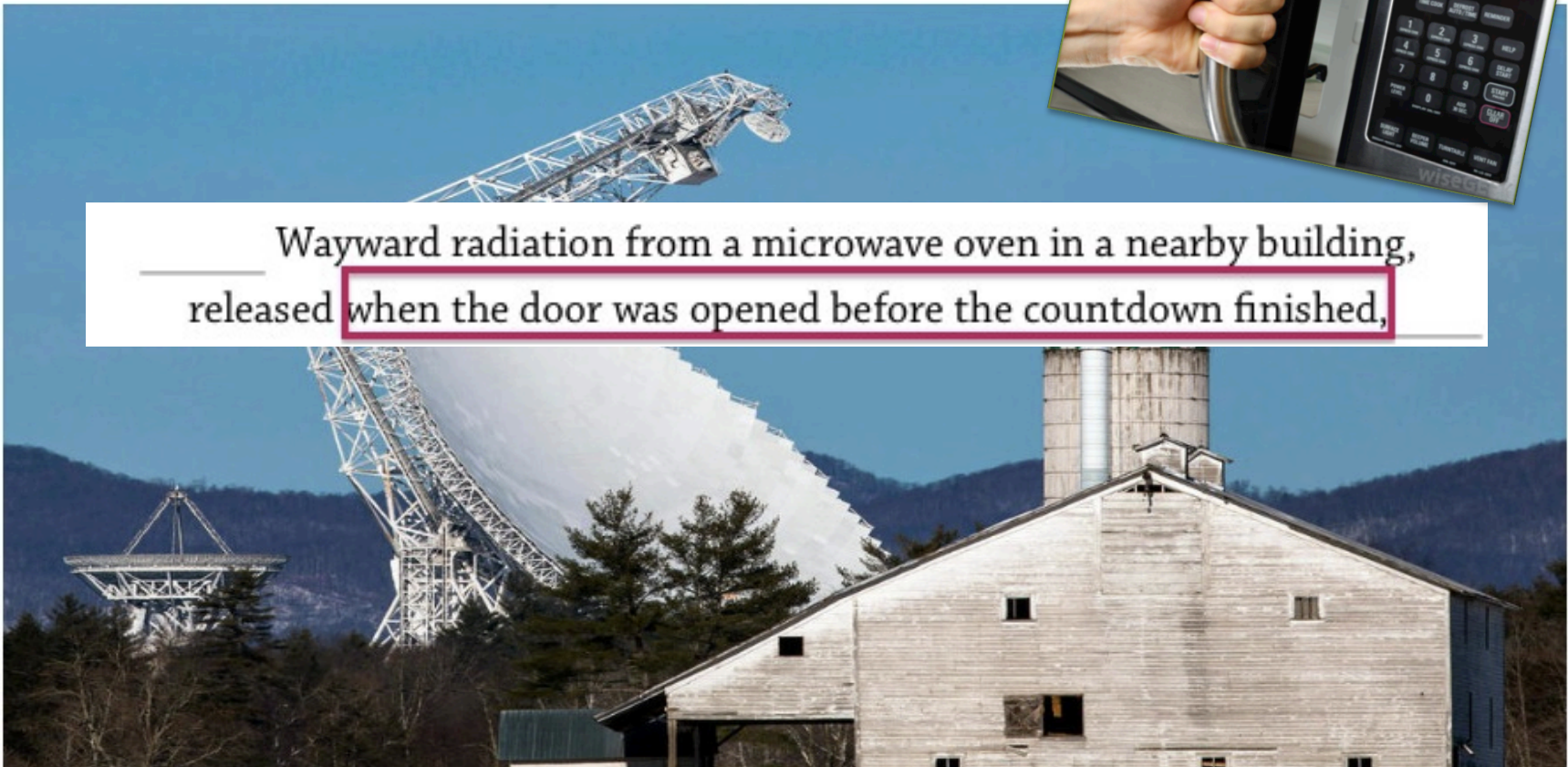
Radio interference wrecks havoc with telescopes

Technology makes life easier for most – but not so much for radio astronomers. Belinda Smith explains.

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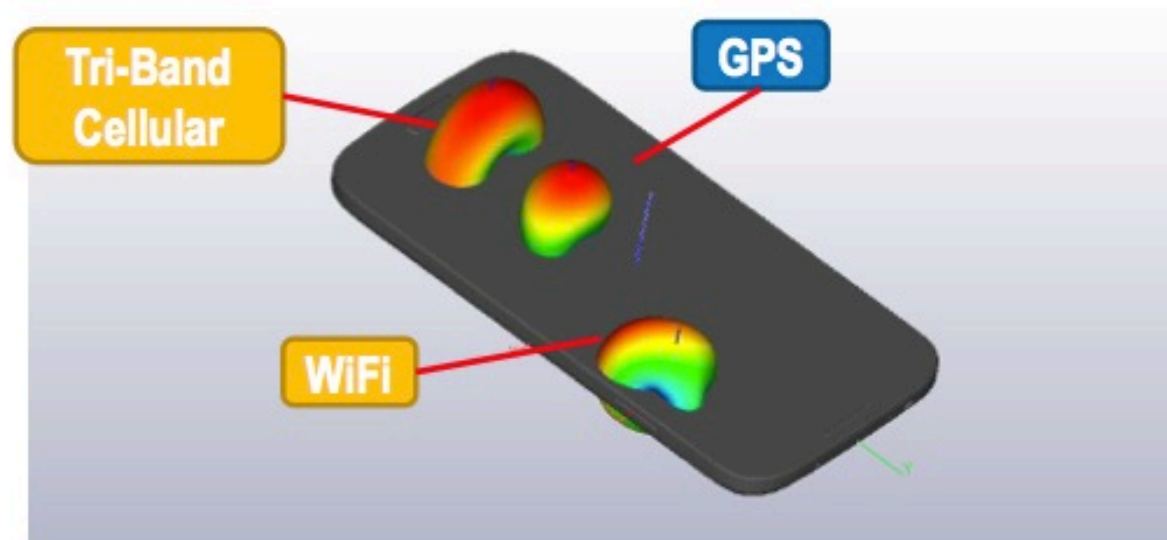


Wayward radiation from a microwave oven in a nearby building, released when the door was opened before the countdown finished,

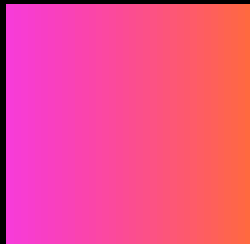


RF Coexistence in a Personal Wireless Device

- Consumer electronic devices represent another RFI coexistence challenge.
- A typical cellphone may have 6, 7, 8 or more antennas/radios that have the potential to interfere with each other.
- Further, the device's electronics generate "noise" that can desense the radio's and degrade performance.
- In this example we will look at a simplified generic cell phone to assess the coexistence/desense.



Source: Dr. Fred German,
Ansys, Inc.



FDMA

TDMA

CDMA

WCDMA

TD-SCDMA

...

Cellular Frequencies



A single cell in an analog cell-phone system uses one-seventh of the available duplex voice channels. That is, each cell (of the seven on a hexagonal grid) is using one-seventh of the available channels so it has a unique set of frequencies and there are no collisions.

A cell-phone carrier typically gets **832 radio frequencies** to use in a city. Each cell phone uses two frequencies per call (one for transmitting, and one for receiving) so there are typically **395 voice channels** per carrier. The other 42 frequencies are used for control channels.

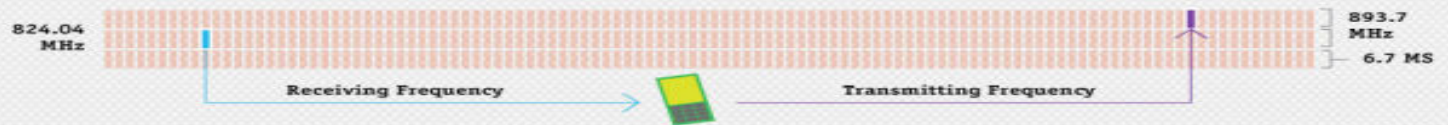


Because cells use a fraction of the available frequencies (to avoid collisions), each cell has about 56 voice channels available. In other words, **in any cell, 56 people can be talking on their cell phone at one time**. Analog cellular systems are considered first-generation mobile technology, or 1G. With digital transmission methods (2G), the number of available channels increases. The most common way of increasing channels with 2G are:

Frequency Division Multiple Access (which puts each call on a separate frequency)



Time Division Multiple Access (which assigns each call a certain portion of time on a designated frequency)



Code Division Multiple Access (which gives a unique code to each call and spreads it over available frequencies)



3G uses similar methods, such as **CDMA2000** (based on 2G Code Division Multiple Access), **WCDMA (UMTS)** (Wideband Code Division Multiple Access), and **TD-SCDMA** (Time-division Synchronous Code-division Multiple Access).

3G networks also have potential transfer speeds of up to 3 Mbps (about 15 seconds to download a 3-minute MP3). For comparison, the fastest 2G phones can achieve up to 144Kbps (about 8 minutes to download a 3-minute song)



Unlocked Phones

A locked phone will only recognize a SIM card from a particular carrier. The *lock* is a software setting (one that can often be overridden with a code). If the cell phone is unlocked, it will recognize a SIM card from any carrier.

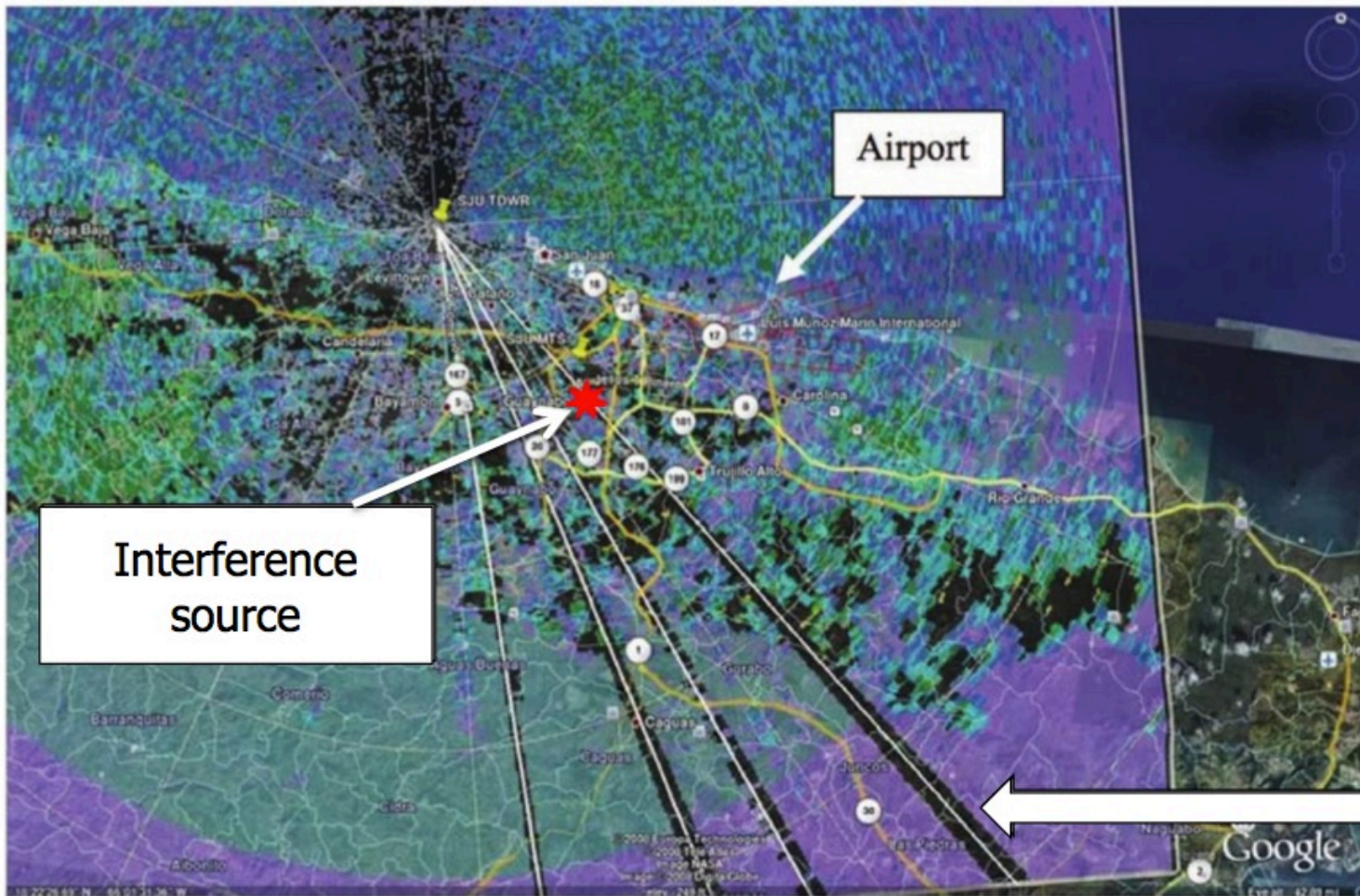
Sources: Bright Hub, Cellphones.org, Gizmodo, HowStuffWorks, Test Freaks

What's RFI?



Without Info Sharing: Malfunctioning Devices Cause Harm

Example: 5 GHz Doppler weather radar & WiFi LAN access point



Field data from an incident in 2009, San Juan, Puerto Rico. NTIA Technical Report TR-11-473

Interference strobes

Thank you!

QUESTIONS?