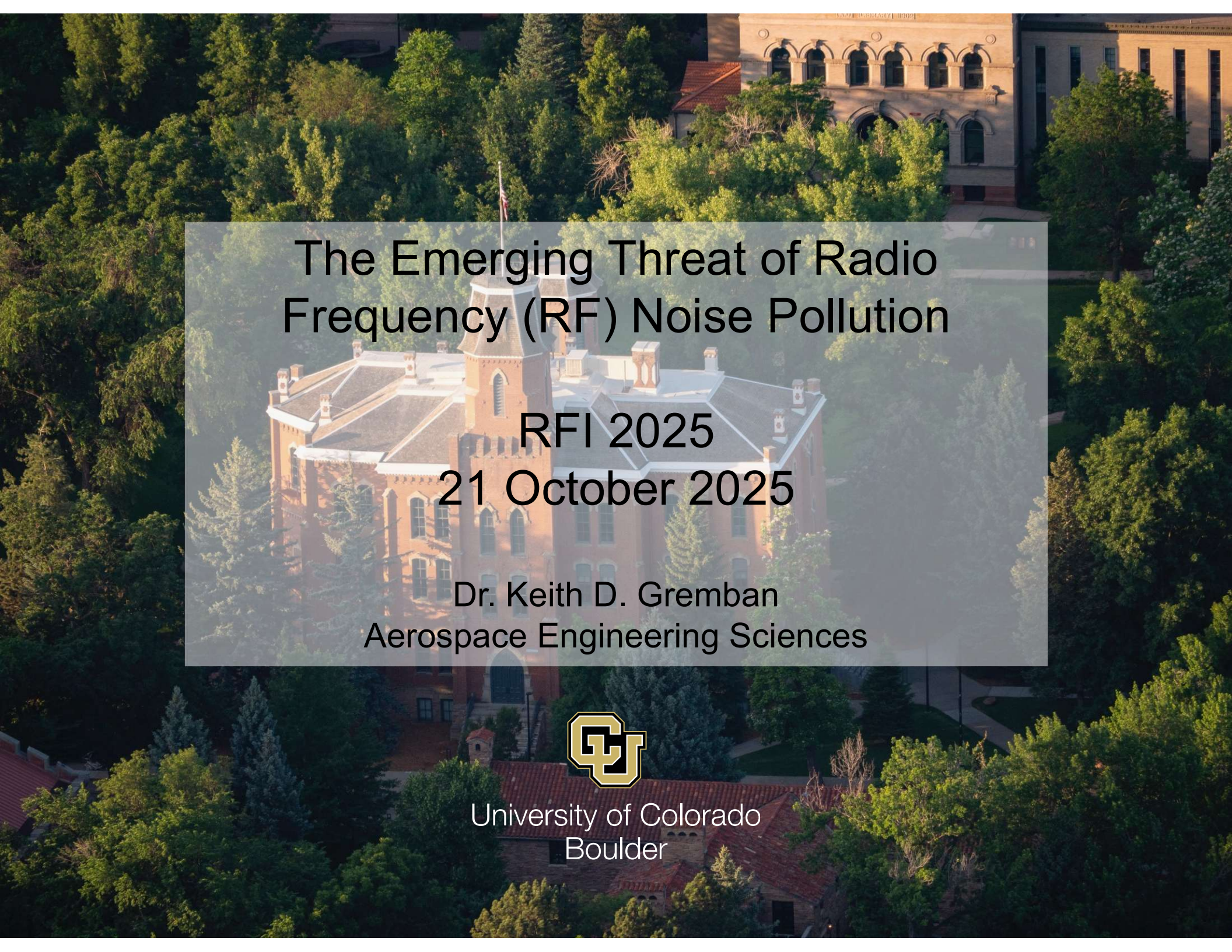

The Emerging Threat of Radio Frequency (RF) Noise Pollution

RFI 2025
21 October 2025

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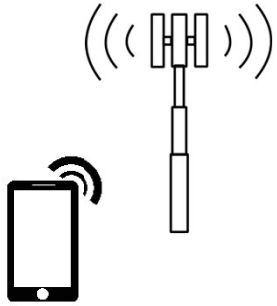
Background in RF Noise Pollution

- **2013 Silicon Flatirons Conference**
  - Radio Spectrum Pollution: Facing the Challenge of a Threatened Resource
- **2023 Silicon Flatirons Roundtable**
  - Invitation only
  - Chatham House Rule
  - Outcomes report: The Challenges of Radio Spectrum Pollution
- **Institute for Telecommunication Sciences**
  - Interference thresholds
  - Aggregate interference measurement and modeling
  - Radio Frequency Interference Monitoring System (RFIMS)
  - Spectrum Monitoring

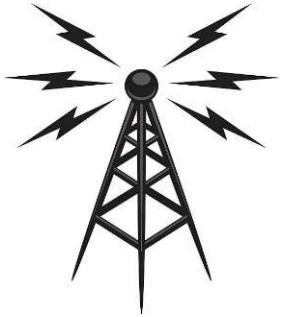
Outline

- **Introduction**
- **2013 Conference Summary**
- **Ten Years Later**
- **Examples and Impacts**
- **Recommendations**

RF Spectrum Use is a Feature of Modern Life



Cell Phones



TV/Radio

Garage Doors

Key fobs

Smart Cars

Avionics

Earth Observation, Communications, GNSS

Utilities

Radar

Radio Astronomy

RF Noise

- **RF Noise is believed to be a growing problem**
  - "radio communication services, both licensed and unlicensed, were entering a 'world of pain' due to increasing levels of radio frequency noise."[1]
  - Radio Astronomy (RA) is increasingly affected by RF noise[2]
    - ***Interference is increasingly coming from cellular systems and satellite communications***
  - Remote Sensing suffers degraded or lost data from RF noise[2]
    - ***Wireless communications is degrading or destroying data***

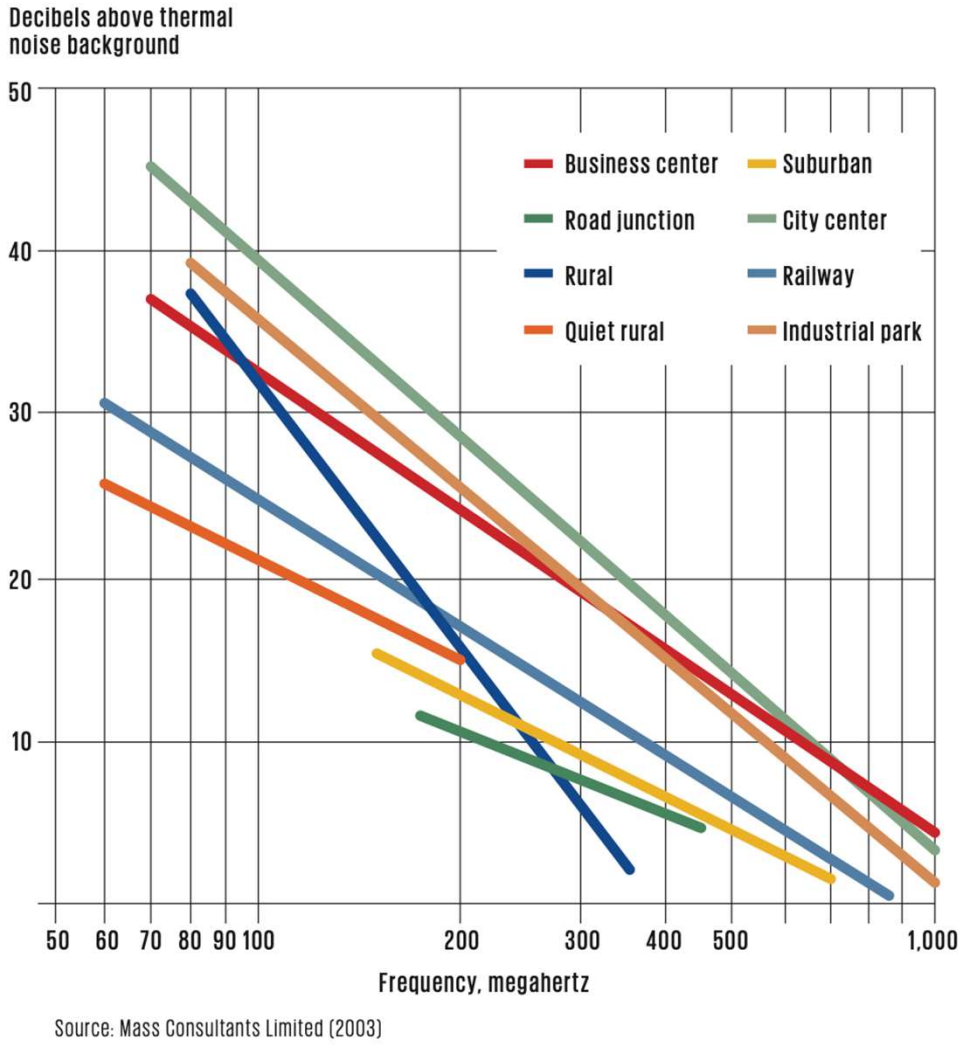
[1] Association of Federal Communications Consulting Engineers, Ex Parte Presentations in ET 16-191 and RM-11779, April 13, 2017
[2] National Academies Press, "Handbook of Frequency Allocations and Spectrum Protection for Scientific Uses," 2015

RF Noise Quantification

- **We don't know the extent of the problem**
  - No systematic study of RF noise in the U.S. has been made since the mid-70s[1]
- **Representative studies**
  - Shared Spectrum Corporation (2010) surveyed 30 – 3000 MHz over 87 hours[2]
  - McHenry et al surveyed 100 – 1500 MHz[1]
  - NTIA/ITS monitored 3.5 GHz activity on U.S. coast[3]
  - NASCTN surveyed out-of-band and spurious emissions from AWS-3 base stations at 1755-1780 MHz; 2155 – 2180 MHz[4]

[1] M. A. McHenry, D. Roberson, and R. J. Matheson, "Phone to Fridge: Shut up!" IEEE Spectrum 52(9): 50-55 (2015)
[2] Shared Spectrum Company, "General survey of radio frequency bands – 30 MHz to 3 GHz," 2010
[3] M.G. Cotton, L.P. Vu, B. Eales, A. Hicks, "3.45 – 3.65 Ghz Spectrum Occupancy from Long-Term Measurements in 2018 and 2019 at Four Coastal Sites," NTIA Technical Report TR-20-548, April 2020
[4] M. Frey, et al, "Measured Emission Spectra of Selected AWS-3 LTE Transmitters," NASCTN Report 4, December 2017

RF Noise: Man-Made Electrical Noise



- **"Man-made noise levels are much higher in cities] than in suburbs or out in the country because cities have a higher concentration of all forms of electrical equipment, computers and radios, and home appliances and systems, as well as industrial equipment"**

Source: McHenry, M.A., et al, "Phone to Fridge:Shut Up!," IEEE Spectrum, Sept. 2015

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2013 Conference Summary (1)

- **Extensive use of radio frequencies is crucial to**
  - Economic well-being
  - National defense
  - Homeland security
- **Radio spectrum can be *polluted* by interference from other radio sources**
  - Noise is radio frequency interference that does not come from an identifiable, intentional radiator
- **Three categories of radio noise:**
  - Natural (not man-made) environmental noise (e.g., lightning, …)
  - Interference from unintentional radiators (e.g., motors, lighting, ….)
  - Aggregate out-of-band interference from intentional radiators

2013 Conference Summary (2)

Measurements

- **We do not know how bad the problem is – need more measurements and analysis.**
- **No standard methodology for measuring noise.**
  - Bad measurements lead to bad data.
- **The measurement process depends on what the researcher is seeking.**
  - Report on measurements should be understandable and comprehensive.
- **Measurements depend on the frequency range.**
- **Most important consideration is aggregate emissions.**

2013 Conference Summary (3)

Takeaways

- **Noise may not be the primary problem in the unlicensed domains**
  - Competition among users for channel access may be the larger issue
- **Scientific understanding of interference is eroding**
  - Most interference complaints are anecdotal
- **Carriers have a lot of interference data**
  - Can carriers be encouraged to share data?
- **Insufficient resources**
  - The EPA has 6000 scientists – the FCC has less than 2000 employees
  - Most FCC employees are not considered “critical” during gov’t shutdowns
- **Environmental models may not translate well to spectrum**
  - Spectrum pollution is less visible to the public

2013 Conference Summary (4)

Takeaways (cont)

- **Strong evidence suggests that the noise floor is rising in higher frequency bands**
  - The scope of the problem is largely unknown because much evidence is anecdotal
  - What measurements do exist often lack transparency and are not systematic
- **Need for systematic, transparent, and scientifically based measurements**
- **Radio spectrum noise pollution matters**
  - e.g., Verizon values 600 MHz spectrum less than 700 MHz spectrum because of noise pollution
- **Insufficient resources**
  - The EPA has 6000 scientists – the FCC has less than 2000 employees
  - Most FCC employees are not considered “critical” during government shutdowns
- **Environmental models may not translate well to spectrum**
  - Spectrum pollution is less visible to the public
- **Non-intentional radiators are the biggest contributors to the noise floor**

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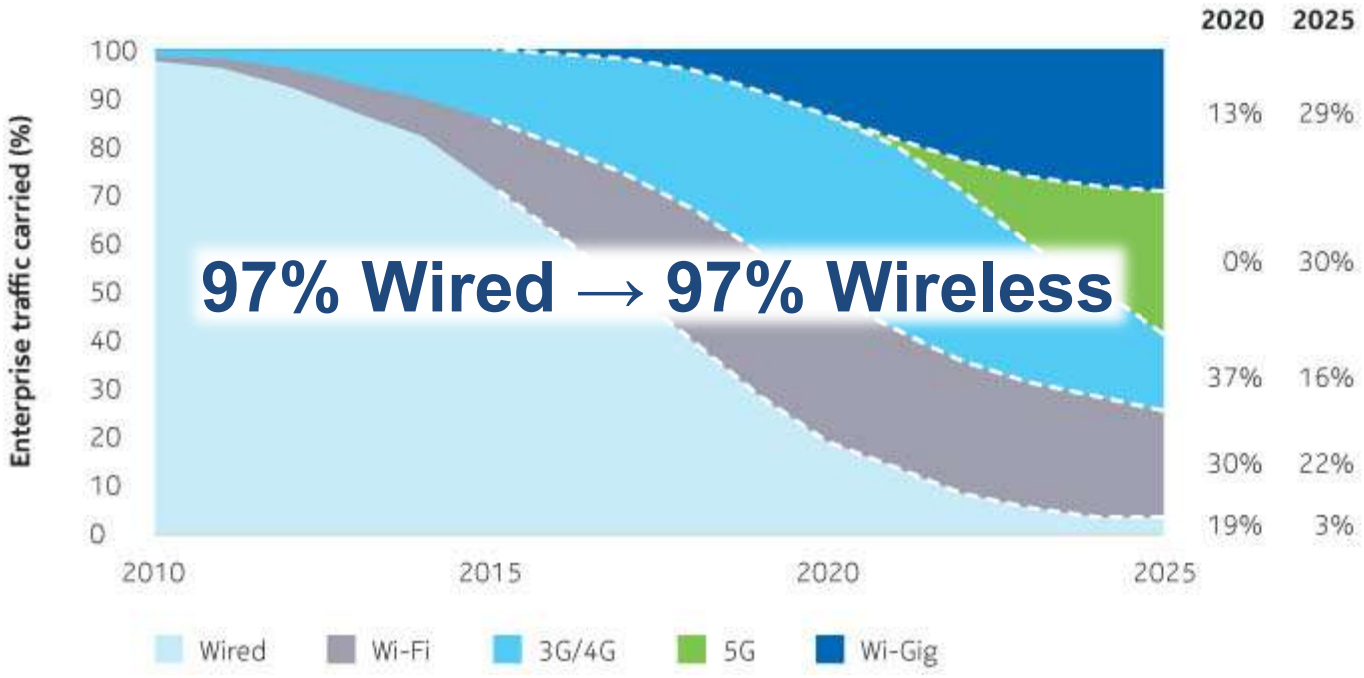
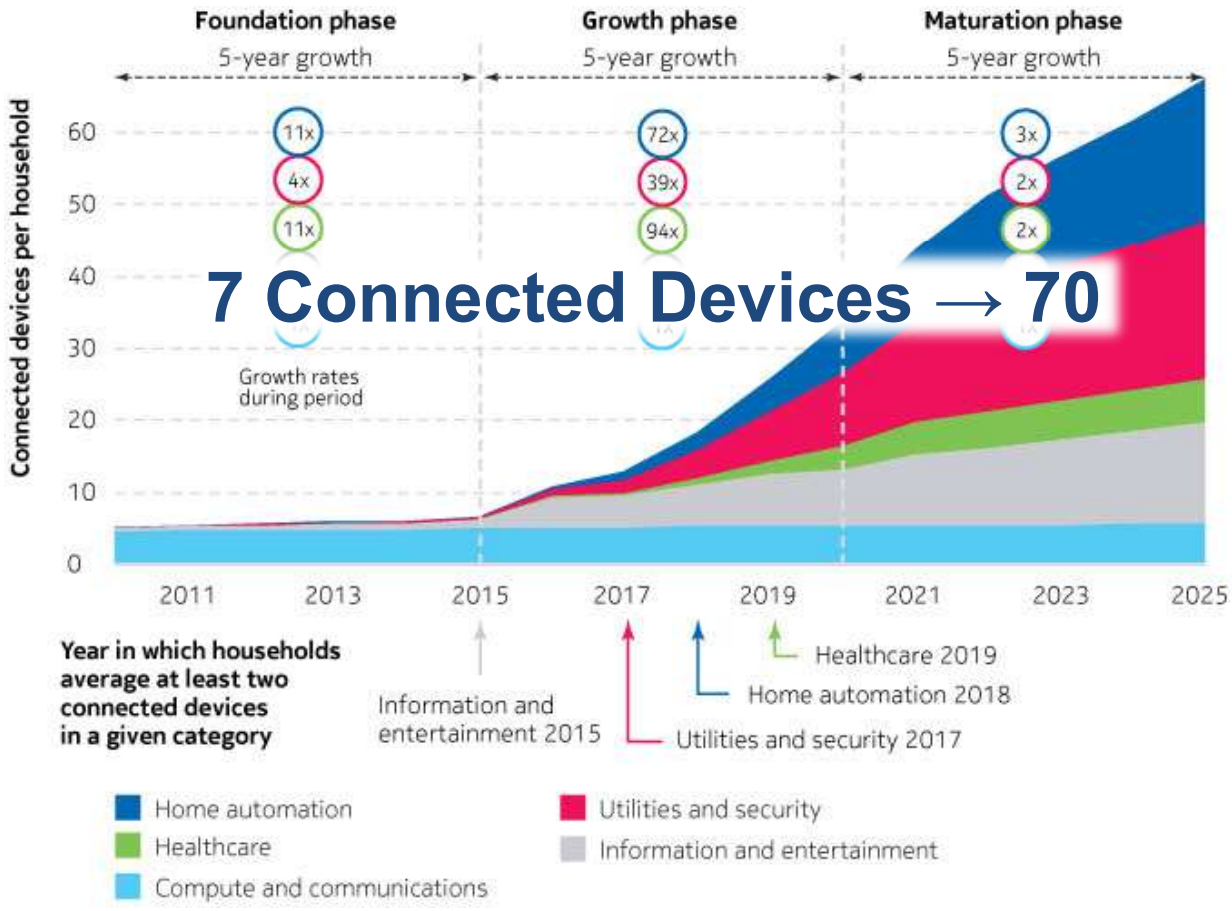
Shift from Wired to Wireless



Marcus K. Weldon, *The Future X Network: A Bells Labs Perspective* (2016)

Growth in Number of Wireless Devices



Marcus K. Weldon, *The Future X Network: A Bells Labs Perspective* (2016)

Socio-Technological Developments

- **Solar arrays**
  - Inverters produce extremely low-frequency interference
  - NREL recommendations for array siting:
    - ***150' from communications equipment; 250' from radar systems***
- **Wind farms**
  - Three mechanisms for interference:
    - ***Radiation from generators and switching components***
    - ***Diffraction of signals***
    - ***Reflection/scattering***
- **Electric Vehicles (EVs)**
  - Known interference up to and beyond HF and VHF bands
- **EV charging infrastructure**
- **Satellites**
  - Communications
  - Onboard electronics
- **Internet of Things (IoT)**

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Some Anecdotes

- **RF noise pollution in Iraq**
  - Military facility in a small valley with initial population of 7,000
  - Population grew to 35,000
  - At ~15,000, military radar and communications began to be affected
- **Suburban expansion in California**
  - Suburban expansion near Edwards Air Force Base
  - RF noise pollution increased as suburbs closed on the base

Example: RF Noise Around the House

- **An enlightening exploration by Andy Clegg**

https://www.youtube.com/watch?v=ewcemoXLzcU

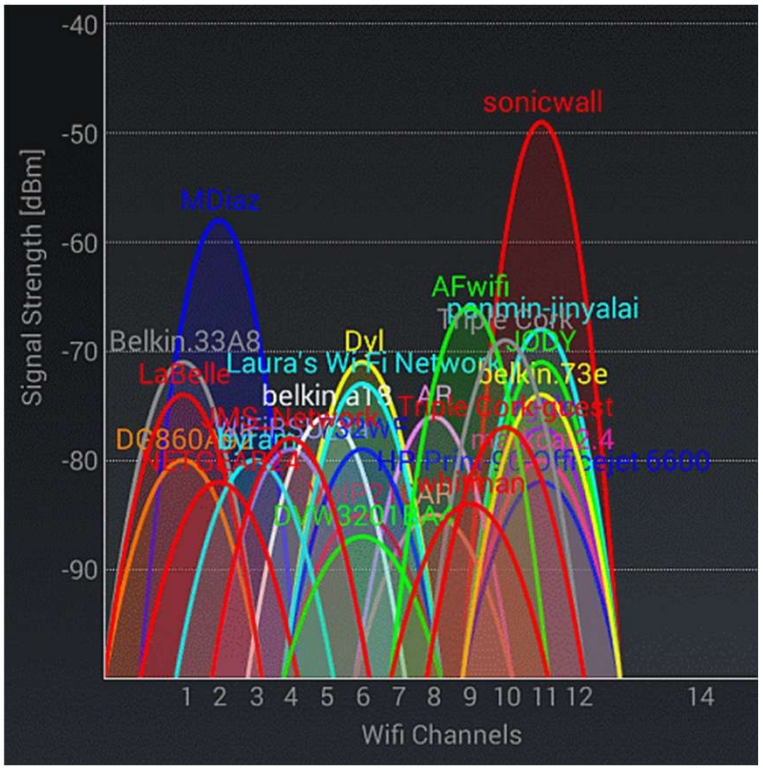
Example: Bug Zapper

Each dot is an instance of a bug being electrocuted at HCRO

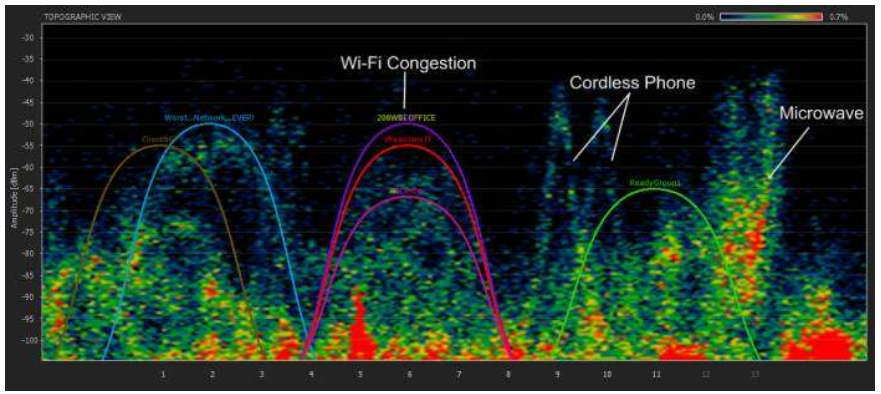
Source: Arvind Aradhya

Example: WiFi Congestion

- **One man's signal is another man's noise**

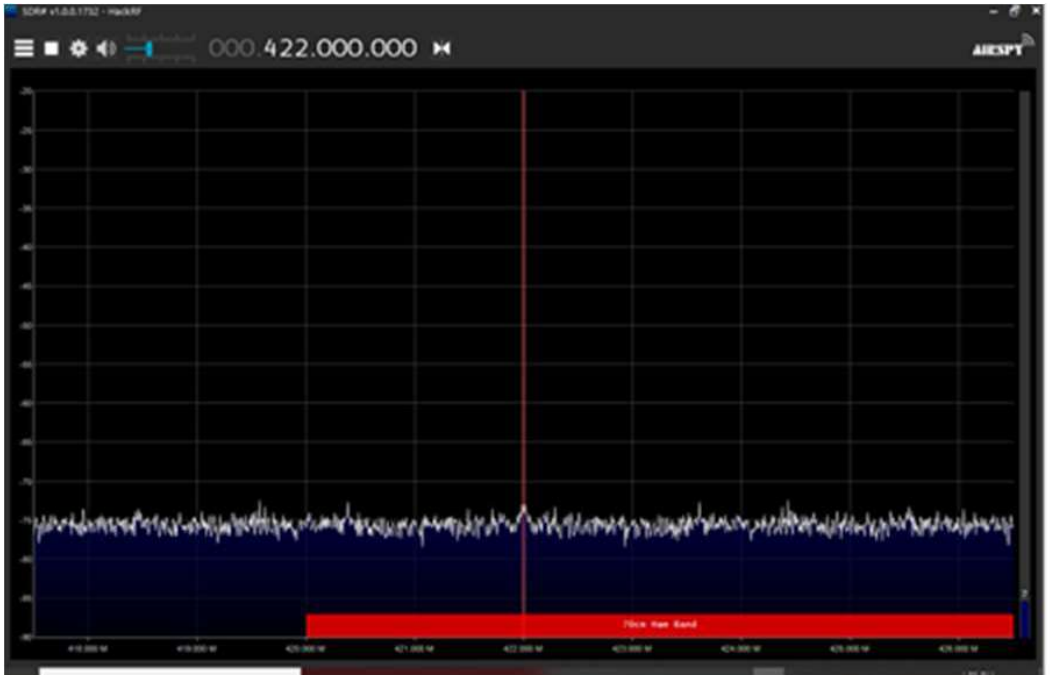


Hotspots

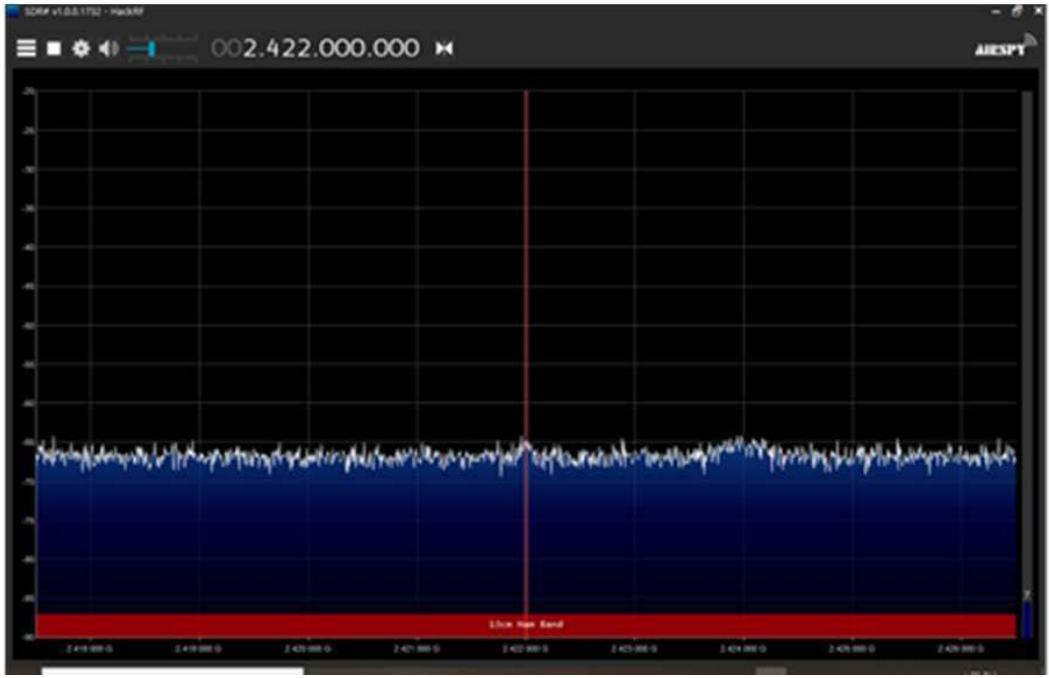


Measured Power

Example: Ambient Suburban RF Noise



0.422 GHz



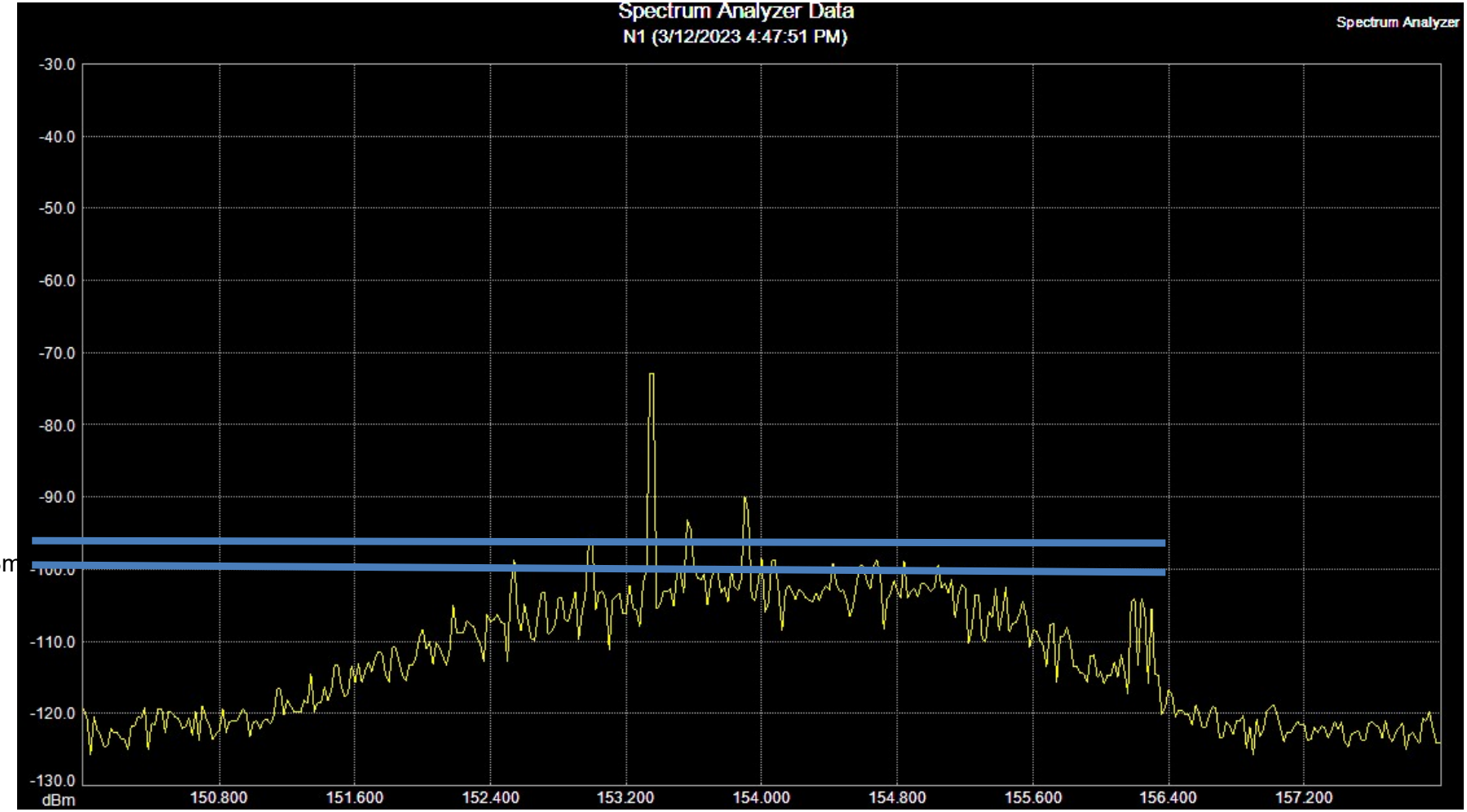
2.422 GHz

Samples taken with a commercial SDR at a suburban site south of Denver.

- Scales are the same between graphs

Example: Ambient RF Noise Outside a Costco

Actual -99 dBm
Measured -102 dBm



Source: J. Blaschka, “Is VHF Dead?” Presentation at 2023 Silicon Flatirons Roundtable**, The Challenges of Radio Spectrum Interference.**

Services in Danger

- **Systems using HF and below are most vulnerable**
  - **Radio-controlled clocks (in the U.S., WWVB signal at 60 kHz).**
  - ***Aeronautical and maritime LF beacons (~200 to 400 kHz)***
  - **AM broadcast band (530 to 1700 kHz)**
  - ***Ham radio (125 to 29,700 kHz)***
  - **Air traffic management on shortwave (118 to 132.45 MHz)**
  - ***Shortwave time services (i.e., WWV on 2.5, 5, 10, 15, and 20 MHz***
  - **CB radio (26.965 to 27.405 MHz)**
  - ***Radio astronomy (particularly lower-frequency observations of pulsars and radio bursts)***
  - **Lightning detection systems (<= 300 KHz)**
  - ***RFID (125 to 134 kHz, 13.56 MHz, 300 MHz to 3 GHz)***
  - **Radio controlled (RC) systems (i.e., model planes, etc.) (27, 49, 50, 53 MHz)**
  - ***Avalanche transceivers (457 kHz)***
  - **Navtex marine international broadcasts (518 kHz)**

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Recommendations

- **Need a standardized method for measuring RF noise**
  - Including comprehensive documentation
  - Scientific data vs anecdotes
  - Measurement and models for aggregate noise
  - Mechanisms for determining noise sources
- **Need systematic measurement campaigns to establish RF noise floor and rate of growth**
  - Coping with the number of sources and environments will require innovation
- **Proactively develop standards, licensing rules, and regulations**
  - E.g., receiver standards
- **Make the results of RF noise pollution more understandable to the general public**
  - RF frequency issues are invisible to the average user of wireless

Sources

- Association of Federal Communications Consulting Engineers, Ex Parte Presentations in ET 16-191 and RM-11779, April 13, 2017
- Clegg, A., “Radio Noise Around the House,” https://www.youtube.com/watch?v=ewcemoXLzcU
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- Silicon Flatirons Conference Report, “Radio Spectrum Pollution: Facing the Challenge of a Threatened Resource,” (2013)
- Silicon Flatirons Roundtable Report, “The Challenges of Radio Spectrum Pollution,” (2023)

Questions?