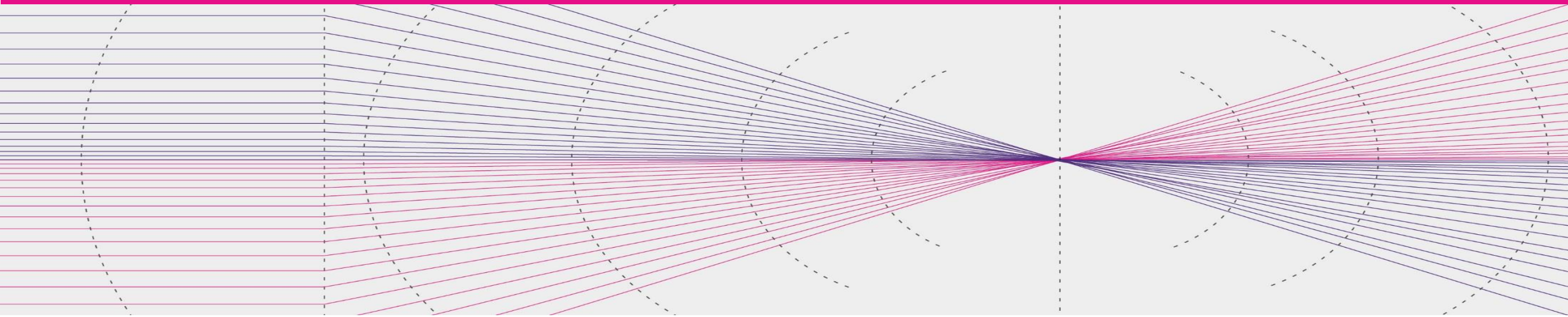
plumpresents

What is out there? Sensing the spectrum

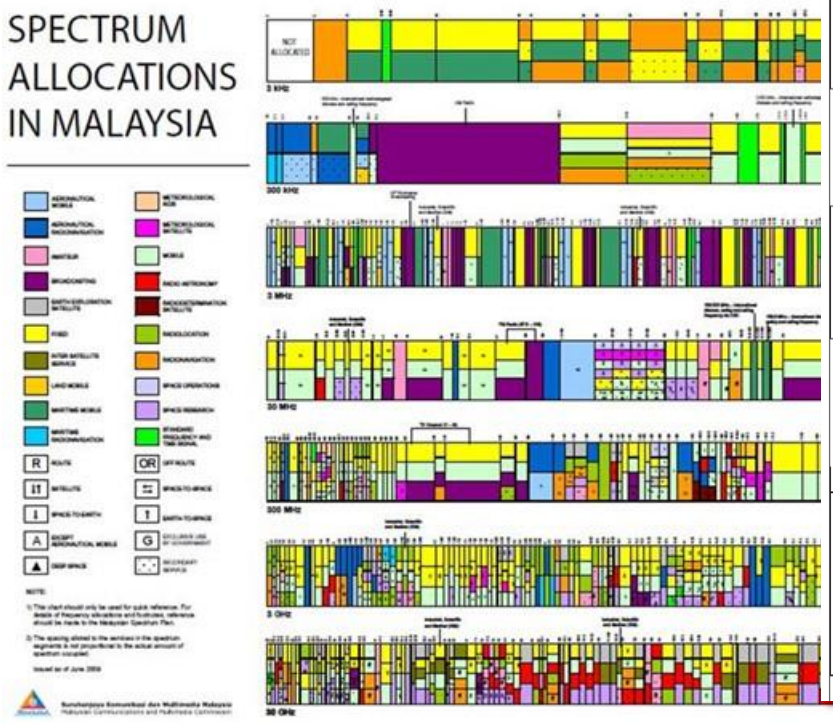
2 December 2022

Richard Rudd



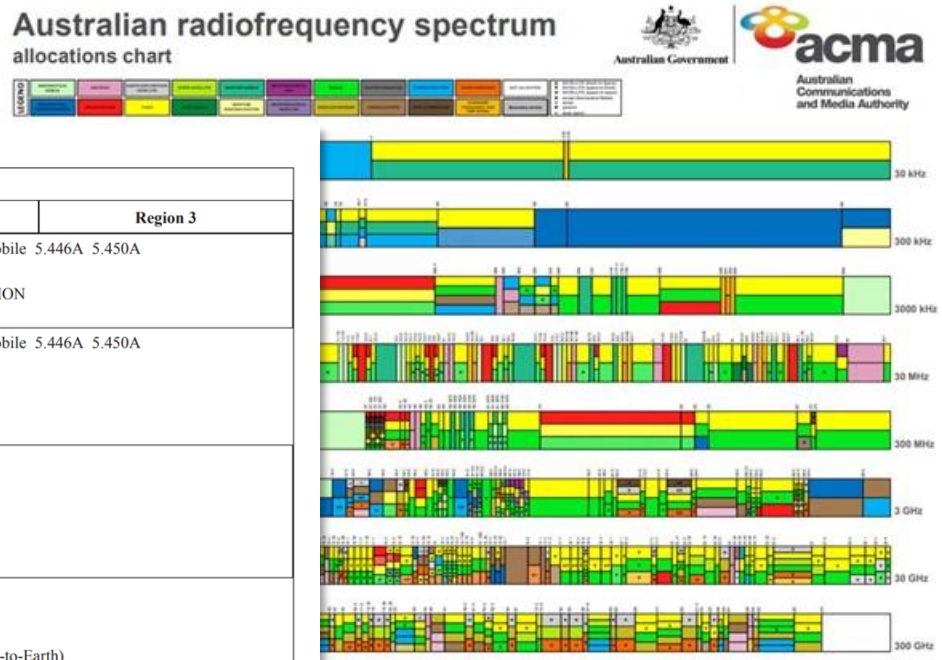
Spectrum allocations

- Looks quite well-defined and organised…
  - … but what's really going on?



5 570-6 700 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
5 570-5 650	MOBILE except aeronautical mobile 5.446A 5.450A RADIOLOCATION 5.450B MARITIME RADIONAVIGATION 5.450 5.451 5.452	
5 650-5 725	MOBILE except aeronautical mobile 5.446A 5.450A RADIOLOCATION Amateur Space research (deep space) 5.282 5.451 5.453 5.454 5.455	
5 725-5 830 FIXED-SATELLITE (Earth-to-space) RADIOLOCATION Amateur 5.150 5.451 5.453 5.455	**5 725-5 830** RADIOLOCATION Amateur 5.150 5.453 5.455	
5 830-5 850 FIXED-SATELLITE (Earth-to-space) RADIOLOCATION Amateur Amateur-satellite (space-to-Earth) 5.150 5.451 5.453 5.455	**5 830-5 850** RADIOLOCATION Amateur Amateur-satellite (space-to-Earth) 5.150 5.453 5.455	
5 850-5 925 FIXED FIXED-SATELLITE (Earth-to-space) MOBILE 5.150	**5 850-5 925** FIXED FIXED-SATELLITE (Earth-to-space) MOBILE Amateur Radiolocation 5.150	**5 850-5 925** FIXED FIXED-SATELLITE (Earth-to-space) MOBILE Radiolocation 5.150
5 925-6 700	FIXED 5.457	



Sensing the spectrum

- Policymaking and engineering design needs robust information
- Different aspects of spectrum sensing:
  - Occupancy
    - Illicit use & Licence verification
    - Technical congestion
  - Monitoring to detect interference
  - Coverage estimation (verification or planning)
  - Understanding the environment
    - Radio noise
    - Anomalous Propagation

Spectrum occupancy

- May need to understand whether assumptions about spectrum use are correct
  - Are unlicensed services using the spectrum?
  - Are licences being adhered to?
  - Is spectrum ‘lying fallow’?
  - Where is congestion an issue?
  - Investigating and resolving interference problems
- Answering these questions may not require calibrated, quantitative measurements
- …but probably implies wide spatial sampling

Monitoring

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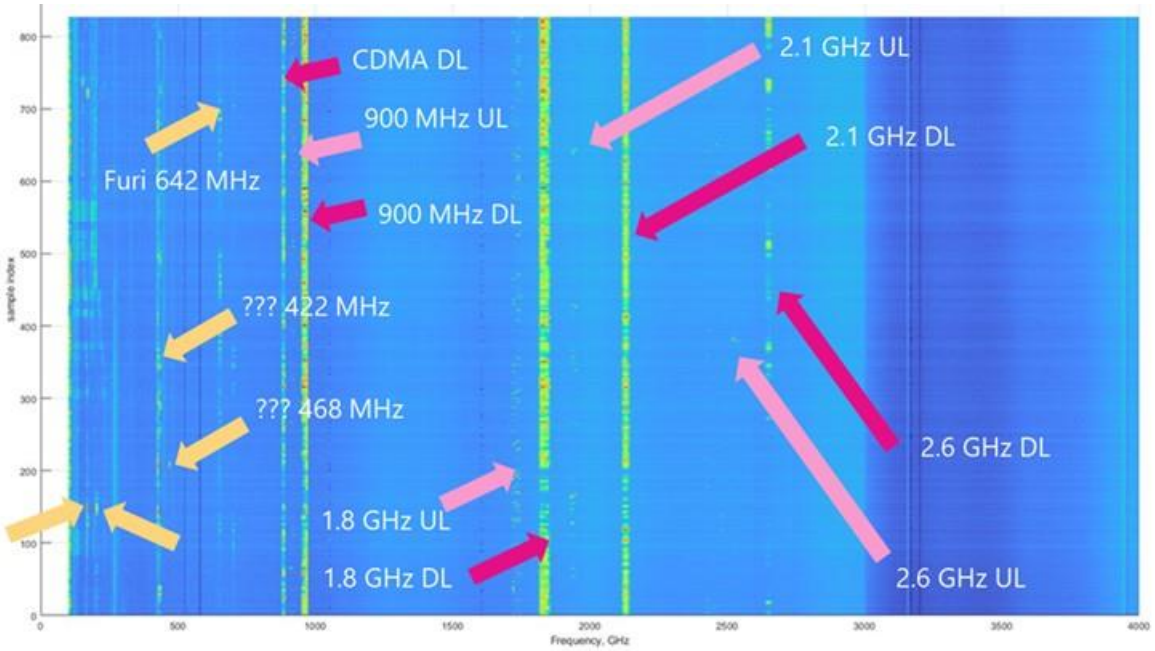
- Many spectrum regulators employ **fixed monitoring networks**
  - In cities, can identify FM pirates, monitor PMR frequency occupancy
  - Build a robust picture of spectrum occupancy changes over time
  - … but gives little insight into geographical distribution
  - Even with several sites, interference sources may be hard to pinpoint, or undetectable
  - Equipment configuration inflexible
- **Mobile or portable equipment** may be more useful in many circumstances
  - Configurable for specific circumstances
  - Requires specialist knowledge
  - Cannot reliably build understanding of usage over time

Broadband, wide-area measurements



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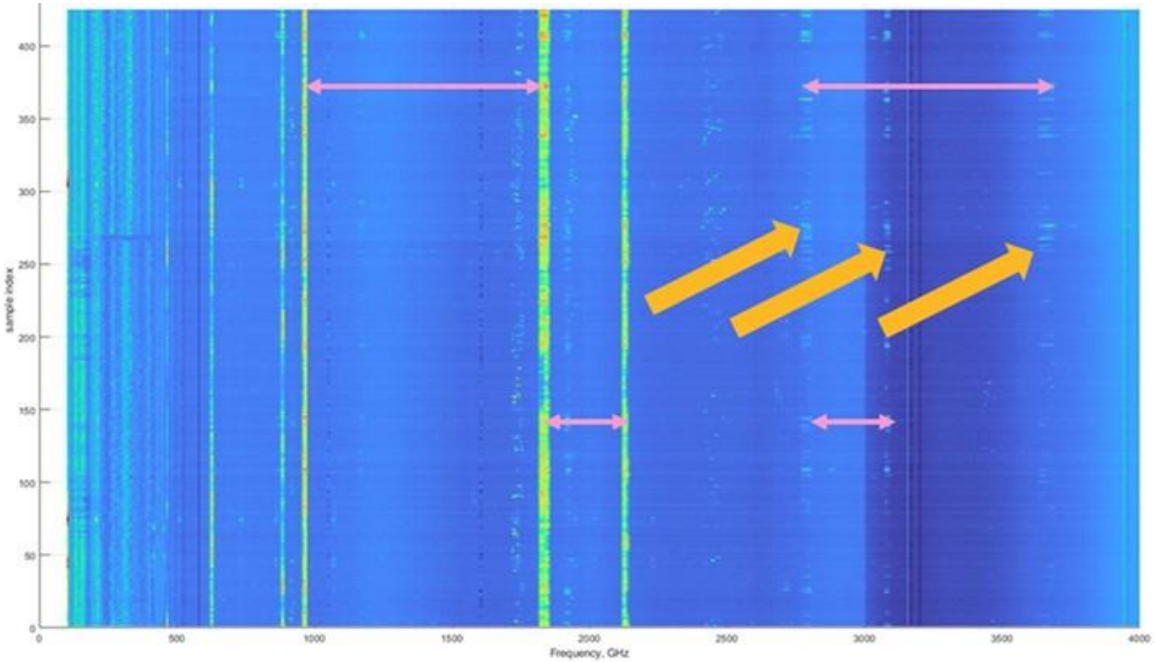
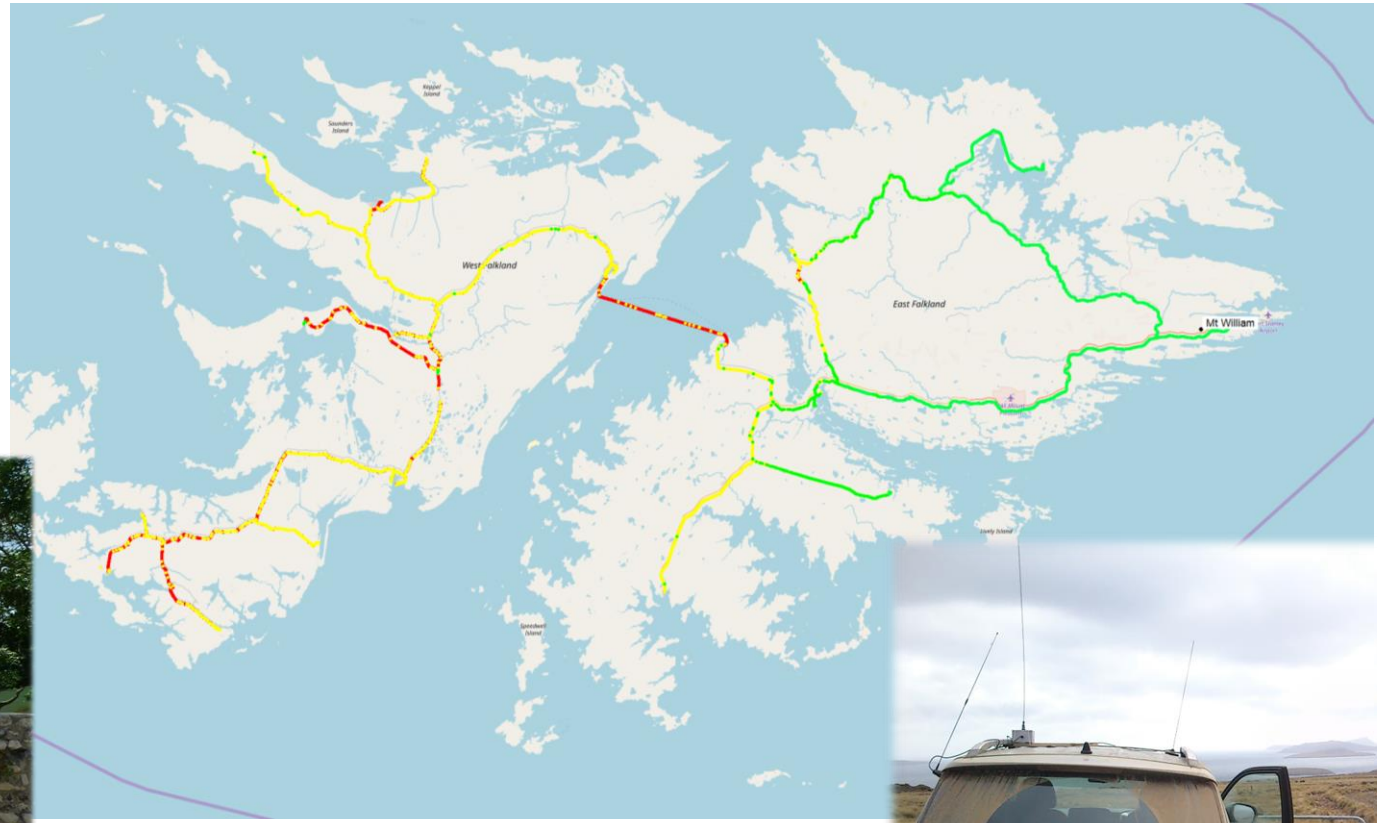


Coverage validation or definition

- More quantitative approach
- Calibration of antennas required
- Relatively simple for broadcast services



Coverage validation or definition

- Cellular services pose greater problem
  - Measure the broadcast channel?
    - More challenging in 5G with beam-based, rather than cell-based channels
    - Need to measure both LTE and NR in non-stand-alone networks
  - But what data rate can be sustained in practice?
- Passive measurement or active network probing?
- Calibrated/external antennas for benchmarking or phone antennas / locations for real-world QoS

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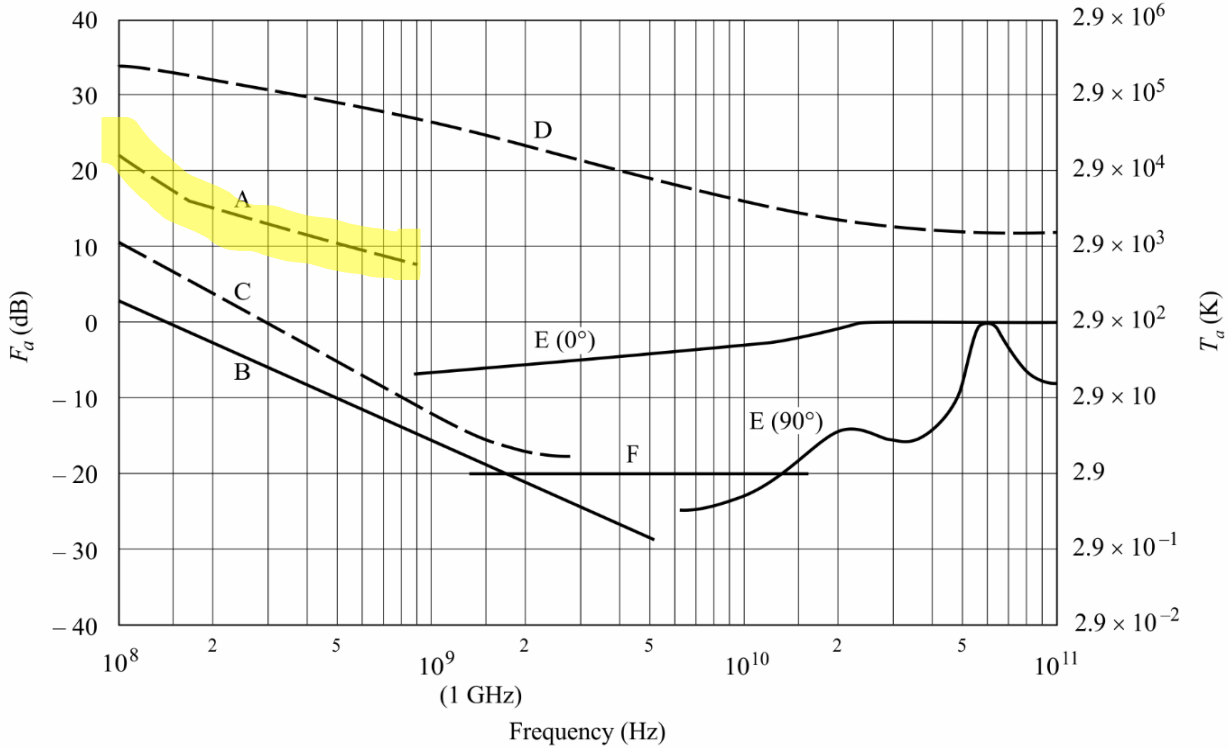
Spectrum quality – radio noise

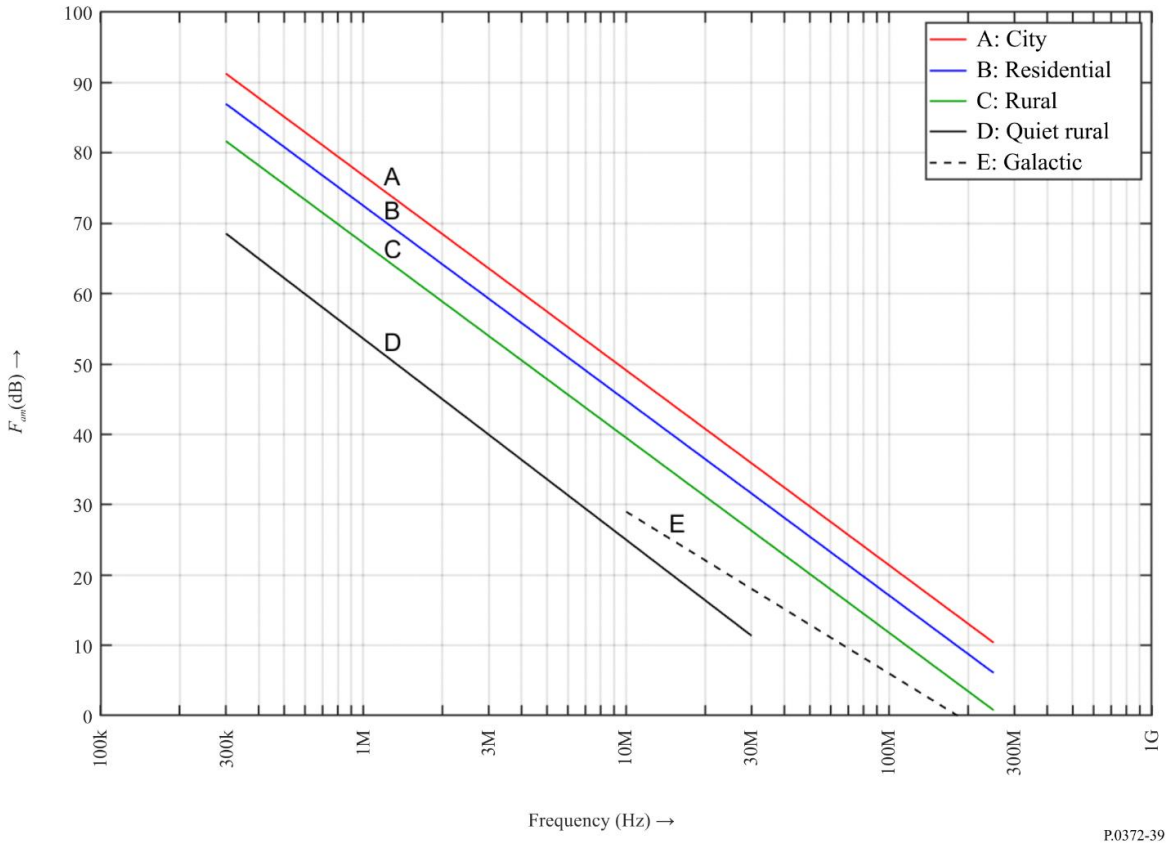
- The most fundamental limit on radio coverage is from noise
  - Limits service area or quality, even in the absence of interference
  - ITU-R Recommendation P.372
  - Natural noise;
    - thermal
    - Atmospheric
    - Celestial
  - Man-made noise



Man-made noise

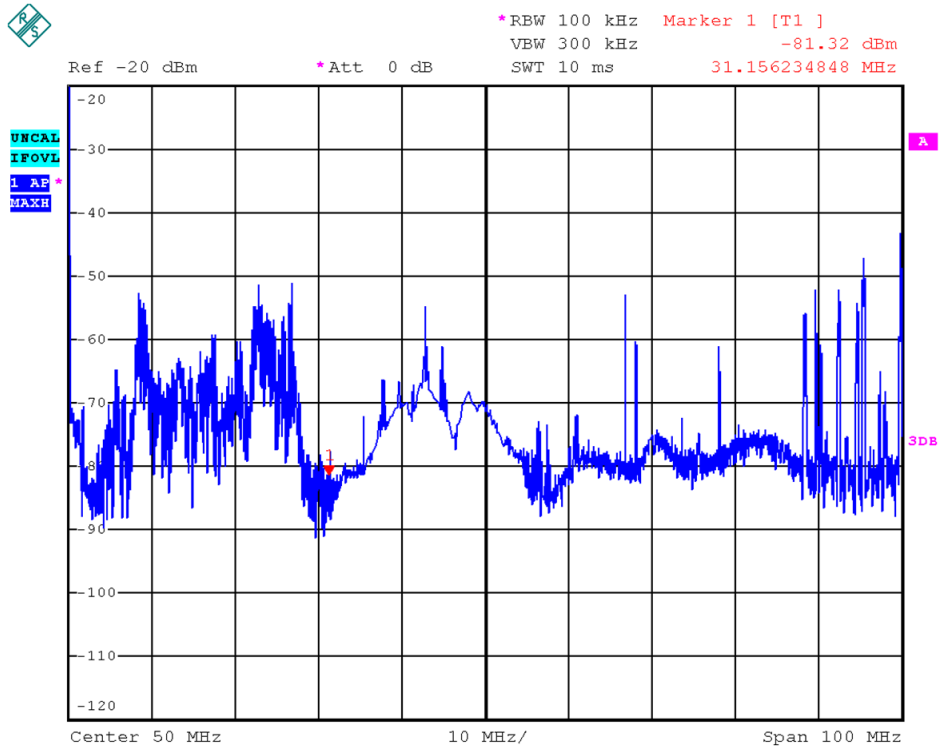
- Man-made noise falls off quite rapidly in the VHF/UHF range
  - More of a constraint on DAB radio at 200 MHz than on PMR services at 450 MHz
  - More of a constraint on PMR at 450 MHz than on cellular at 800 MHz
- Current work within ITU-R SG3 on measurement methods:
  - *"At present, insufficient measurement data are available to describe the expected levels of indoor AWGN man-made noise."*

Outdoor man-made noise levels (P.372-16)



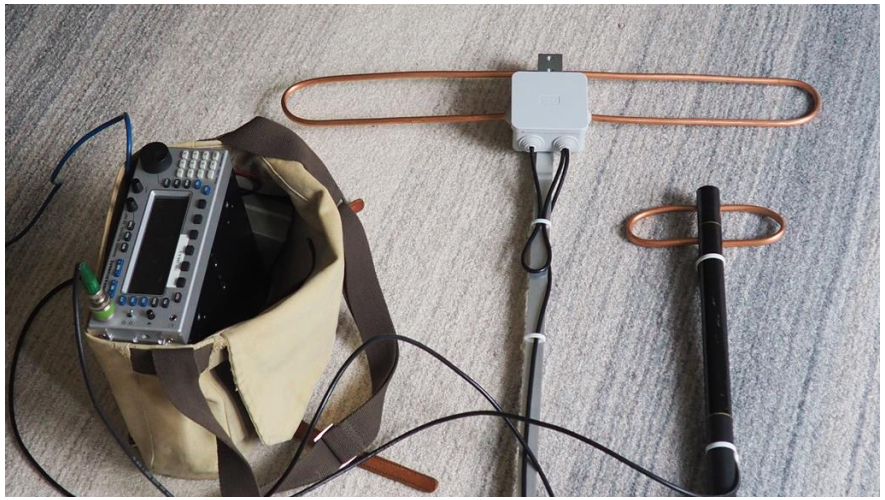
Indoor man-made noise

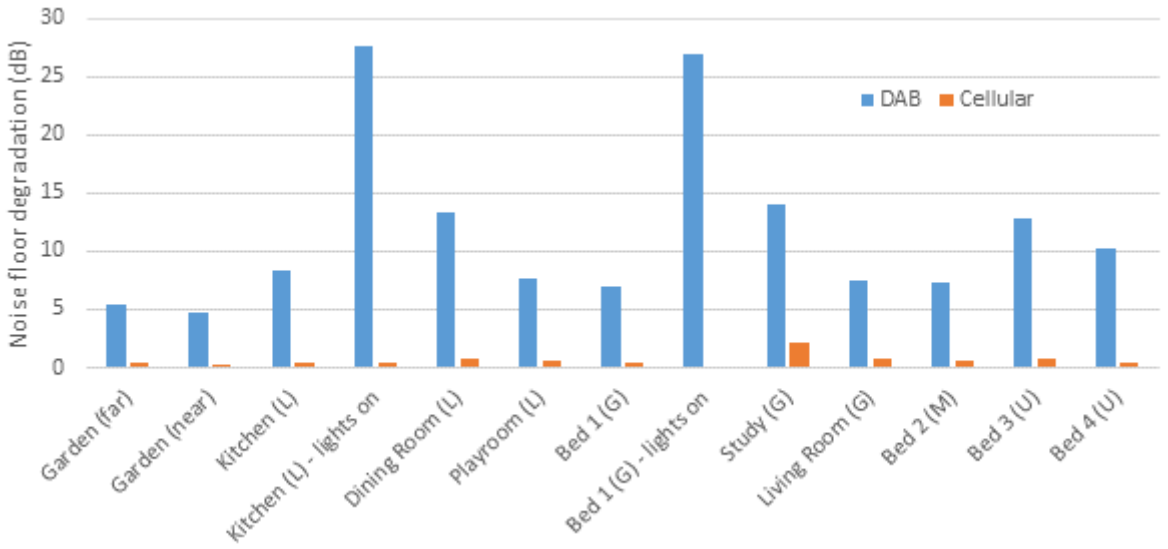
- Growing problem of man-made noise
  - Switch-mode power supplies
  - xDSL
  - Homeplug
  - Switch-mode power supply units (‘wall warts’) often found not to meet EMC standards
  - Replacing 12V halogen lights with LED often causes an increase in interference



Man-made noise

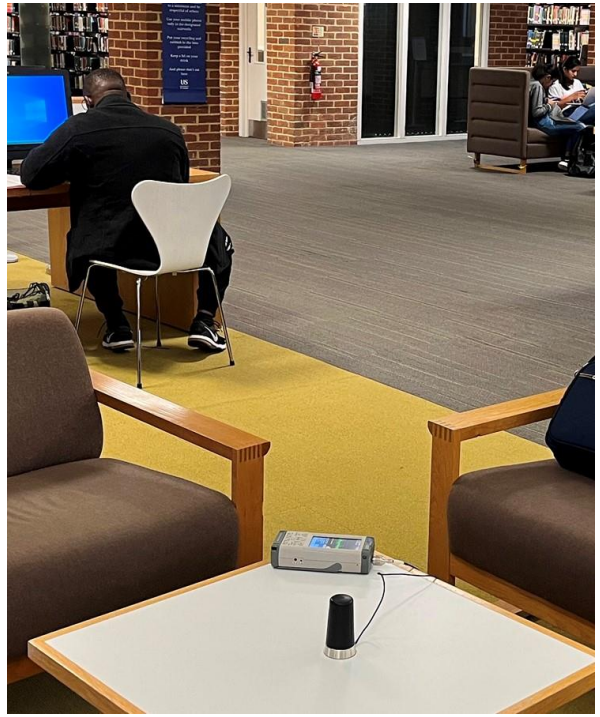
- Measurement
- Sampling problem
  - Statistics vary dramatically over very small distances
  - One room in a house might have noise levels 20dB (100x) greater than an adjacent room

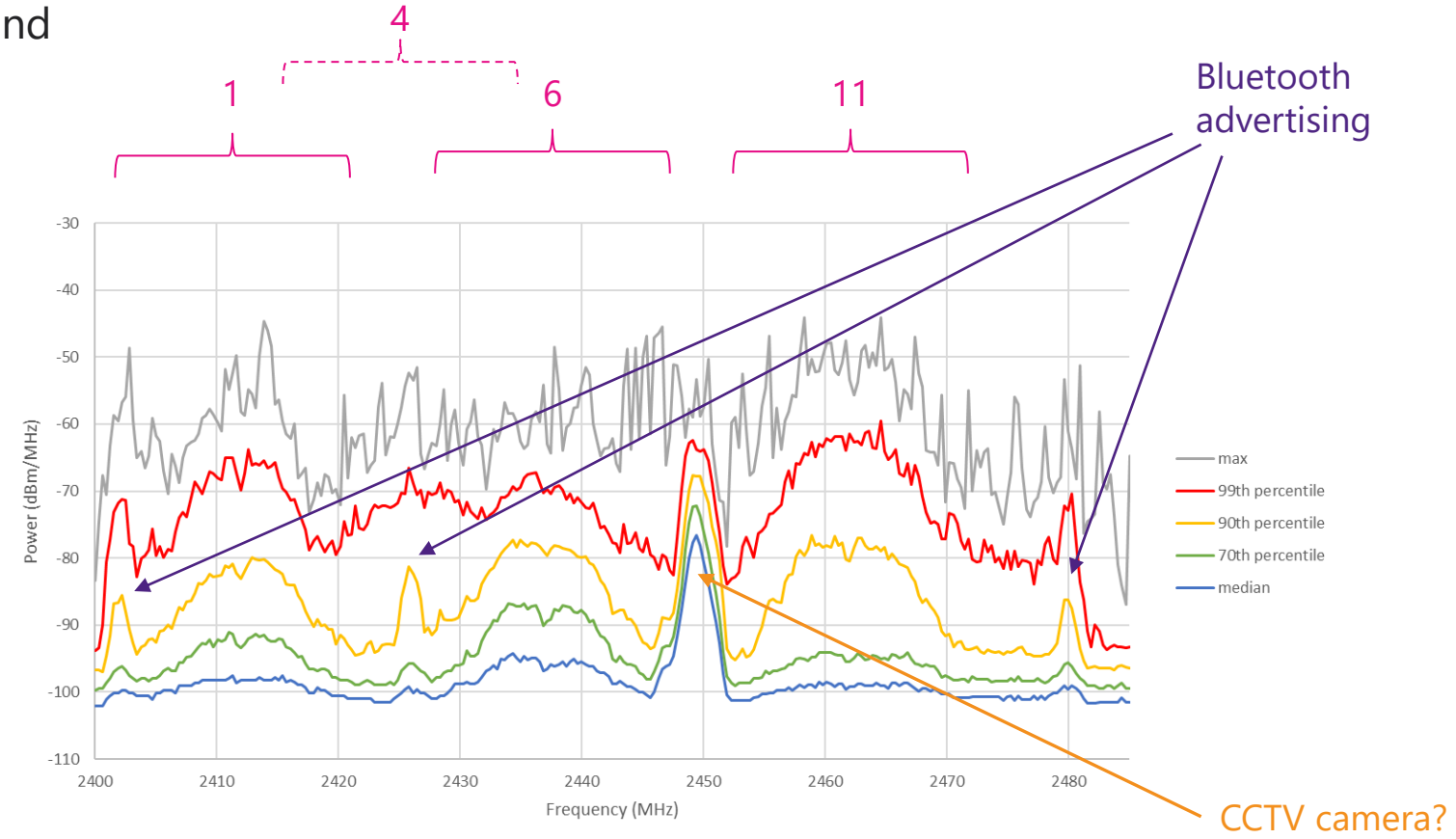




Spectrum congestion

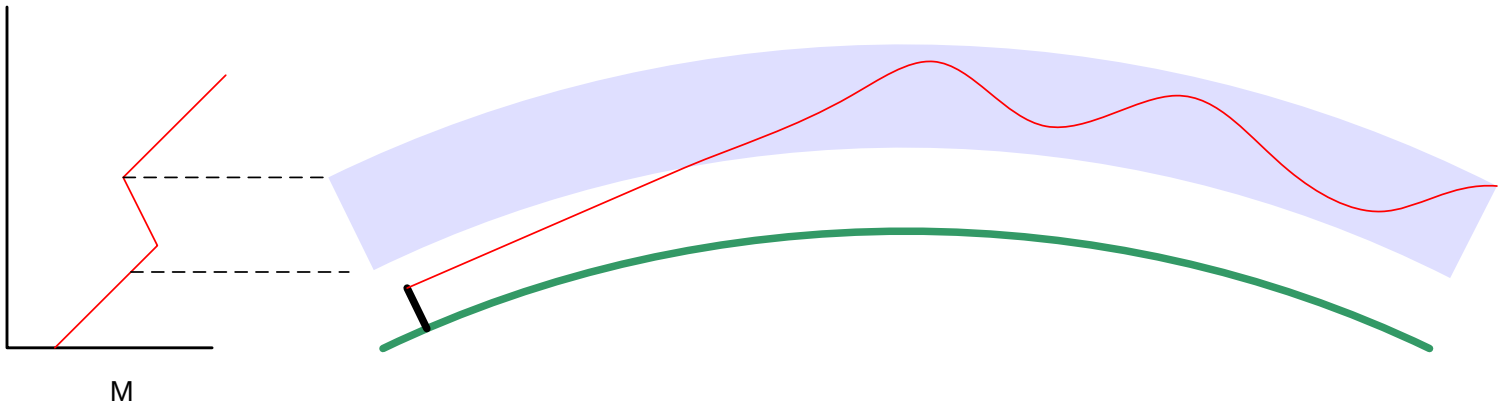
- A similar problem of spatial sampling arises when looking at spectrum congestion at higher frequencies
  - E.g. ‘hotspots’ in the 2.4 GHz band





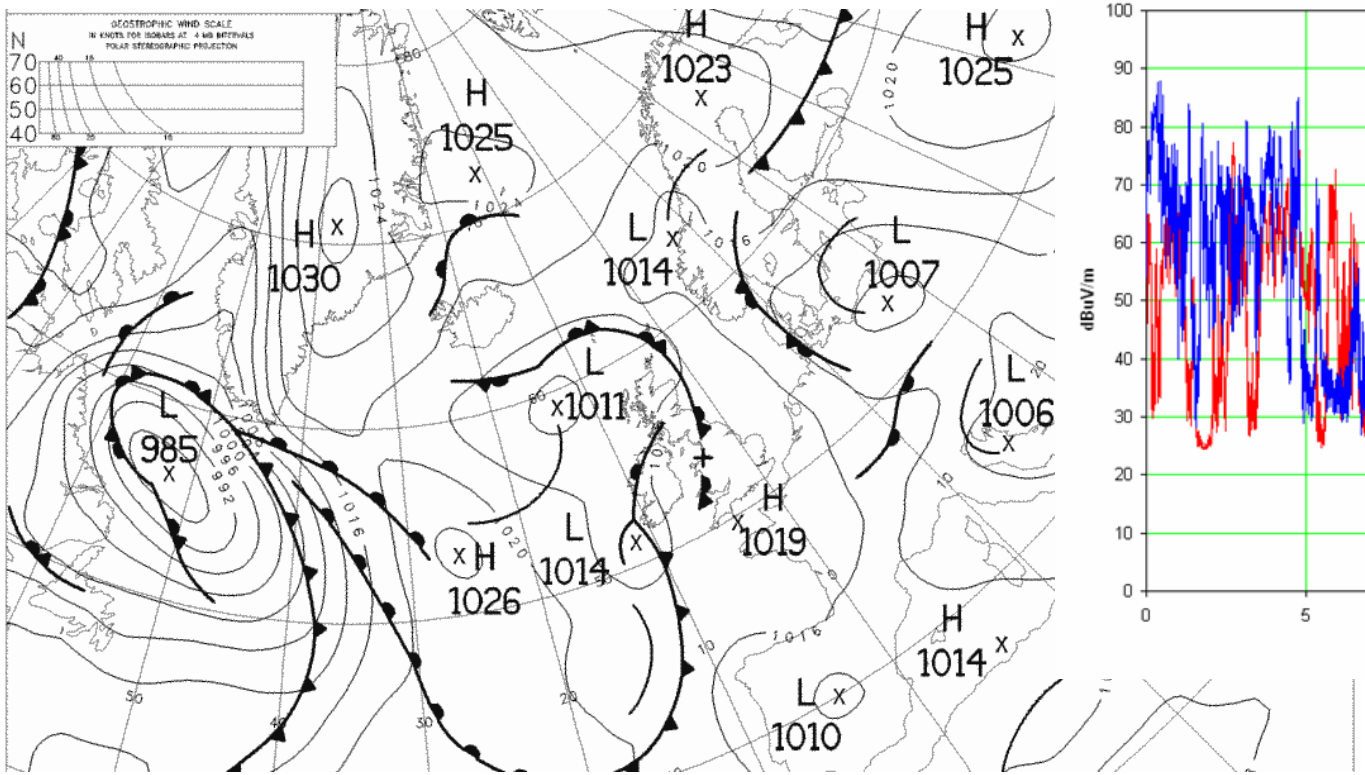
Temporal variability

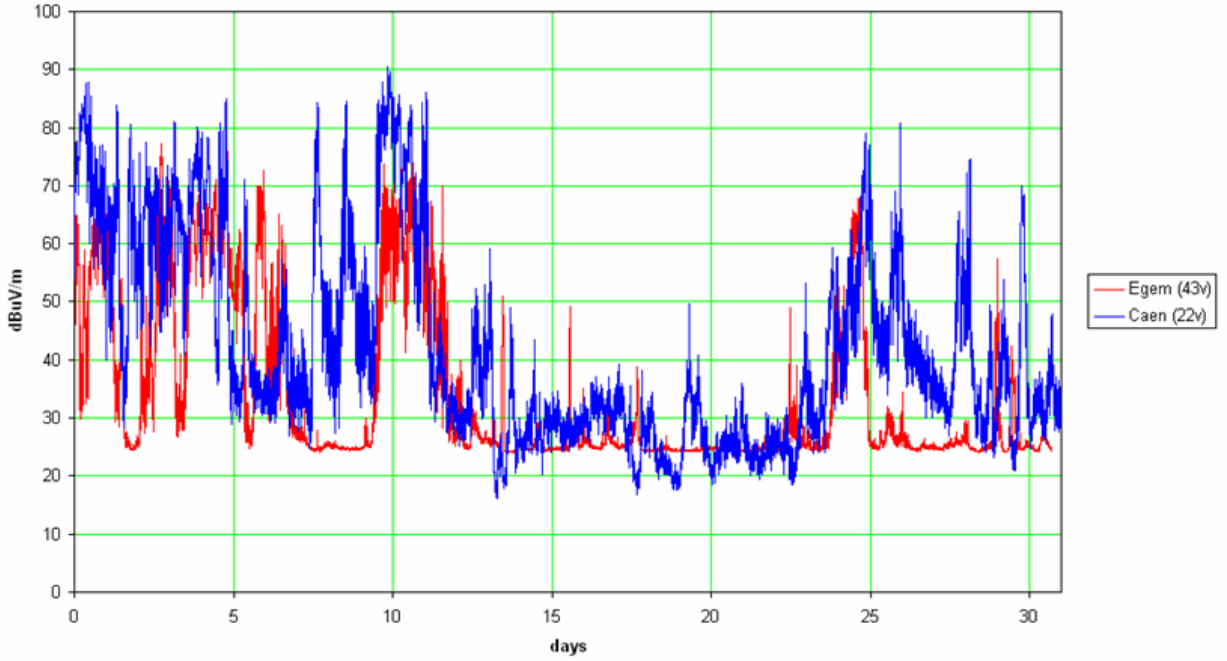
- The spatial variability of signals may make sampling difficult / time-consuming / expensive
- …and so can temporal variability
- Changes in the refractivity of the atmosphere can cause short-lived but very large enhancements of signal strength



Long-term measurements

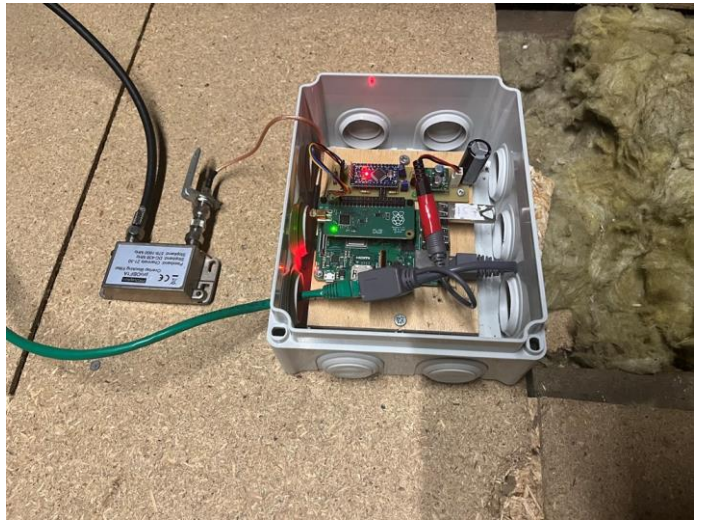
- At UHF frequencies and above, enhancements of ~50dB may be seen for 1% time (3 days/year)
  - Gathering such statistics requires a commitment to long-term measurement





New methods

- The increasing density and diversity of spectrum users makes it increasingly important to have a clear understanding of ‘what is out there’.
- Technology is helping
  - Availability of cheap (quasi-disposable) hardware
  - Software-defined (i.e. very flexible & reconfigurable) radio



New methods

- Drones
  - Stability?
  - Antenna design & calibration?
  - Regulatory problems!
- Crowdsourced data
  - Trade quality for quantity
  - Needs good understanding of derivation
  - Uncertainty budget

- There is no general-purpose solution – a toolkit approach is required

Discussion

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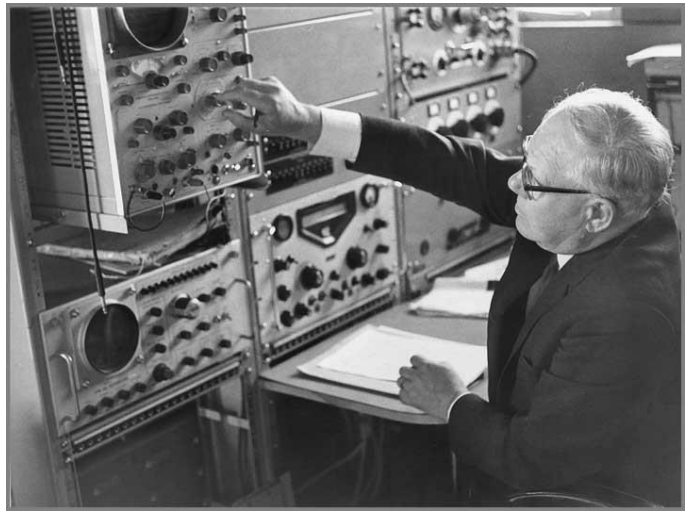

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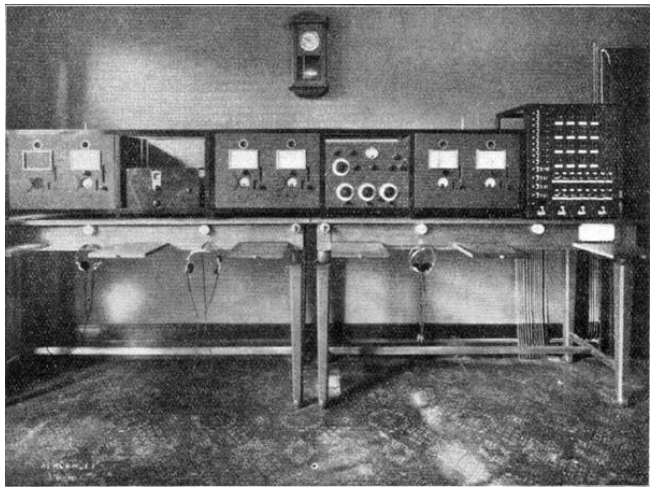
Q & A



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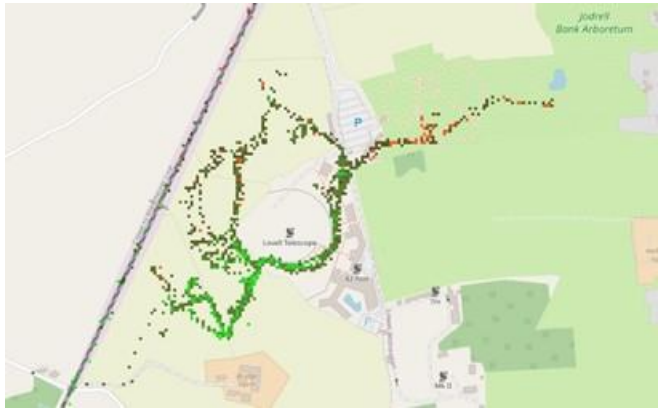

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