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Closing the Loop for Accountable Interference-free Spectrum Sharing with Passive Radio Receivers

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Need: Reactive interference management for sharing protocols

1. Modeling: Interference may be more severe than predicted
2. Management: When interference occurs, how will it be turned off?

If avoidance is only answer → conservative, inefficient sharing

E.g. lawsuit re: μwave relay & WiFi sharing 6 GHz band [1]

"The FCC has no plan to mitigate the interference when it inevitably occurs. … it will be impracticable, if not impossible, for the FCC to identify and remove specific devices causing interference."

[1] J. Marsh, AT&T statement on FCC order to allow unlicensed devices in 6 GHz band, April 2020, press release, AT&T Executive Vice President of Regulatory & State External Affairs.

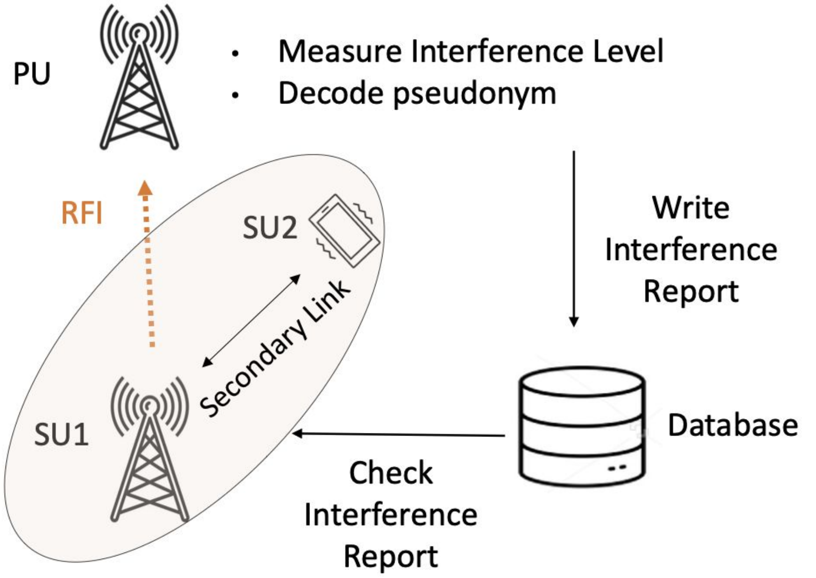
Pseudonymetry system description

Primary User (PU): Licensed, Priority. E.g., radio astronomy receiver.

- When interference detected, demodulates pseudonym, writes report to a database

Secondary User (SU):

- Generates random pseudonym
- Watermarks RF transmissions
- Checks DB to see if its pseudonyms were reported
  - Vacates band if so



Pseudonym Database: records PU interference reports & responds to queries from SUs for pseudonym reports

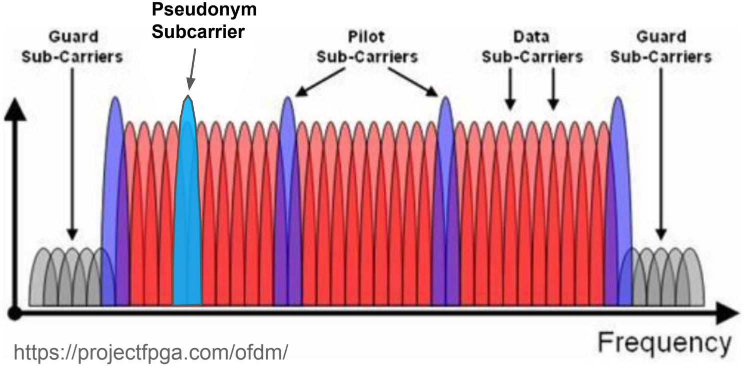
[1] Meles G. Weldegebriel, Jie Wang, Gregory Hellbourg, Neal Patwari, Watermarking of OFDM for pseudonymetry: analysis and experimental results, ICC 2024 Workshop on Catalyzing Spectrum Sharing via Active-Passive Coexistence, 9 June 2024.

[2] Meles Gebreyesus Weldegebriel, Neal Patwari, Ning Zhang, and Jie Wang, Pseudonymetry: Precise, Private Closed Loop Control for Spectrum Reuse with Passive Receivers, 2022 IEEE Intl. Conf. on RFID, 17 May 2022, pages 91-96.

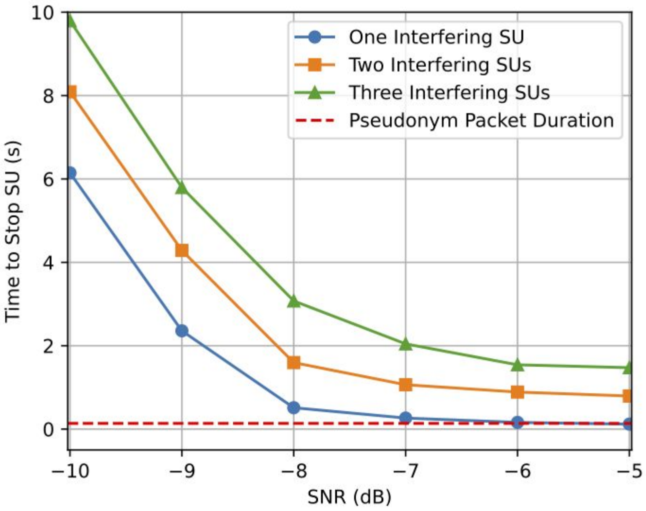
Pseudonymetry Implementation & Results

Full system OTA 3.4GHz implementation on POWDER
https://github.com/StopSec/StopSec-System

- Watermarking: coded on-off modulation of 1 “pseudonym subcarrier” at 1-2 bits per packet
- Pseudonym receiver uses energy detector, noise-adaptive RX, correlation with known code

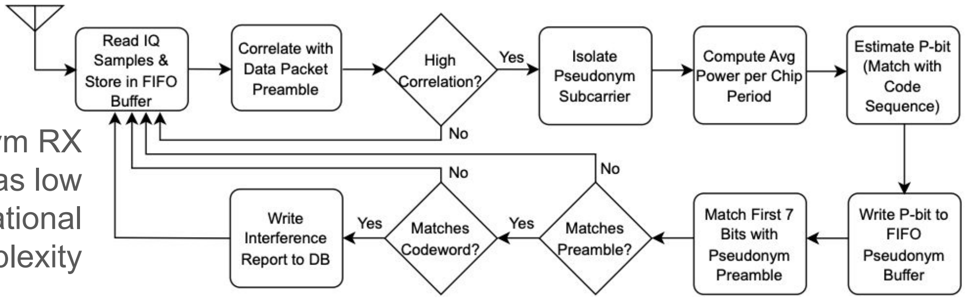


https://projectfpga.com/ofdm/



Stops multiple SUs, 1-2 s

Pseudonym RX has low computational complexity



Meles Weldegebriel, Zihan Li, Dustin Maas, Greg Hellbourg, Ning Zhang & Neal Patwari, [Sensing and stopping interfering secondary users: validation of an efficient spectrum sharing system](), arXiv:2507.13554 [eess.SP], 17 July 2025.

Security of sharing with reactive management

Privacy-Preserving:

- Random, self-generated, unlinkable pseudonyms
  - No device identifiers/metadata logged; PU records only {pseudonym, timestamp, channel}.
- Anonymity over time
  - Rotate pseudonym after each completed transmission to prevent tracking/fingerprinting.
  - TTL expiry prunes stale pseudonyms to curb long-term linkability and reduce spurious blocks.

Secure Database:

- RBAC + authenticated APIs
  - Only PUs/trusted proxies can write; Others read-only/denied
  - Input validation + write logging for traceability; Valid only if:
    - 1): Correct structure/type of pseudonym (i.e., pseudonym decodes to exactly 26 bits after FEC);
    - 2): Physically/timely plausible (i.e., now – t_report ≤ max propagation/processing window; entry isn't expired; channel matches PU's band; etc.)

Implications for radio astronomy observatories

Radio Astronomy & Spectrum Use

- Protected bands are essential but not sufficient for deep sensitivity
- Observations often extend beyond protected bands into spectral gaps
- Some bands remain unexplored due to continuous RFI

Spectrum Management & RFI Detection

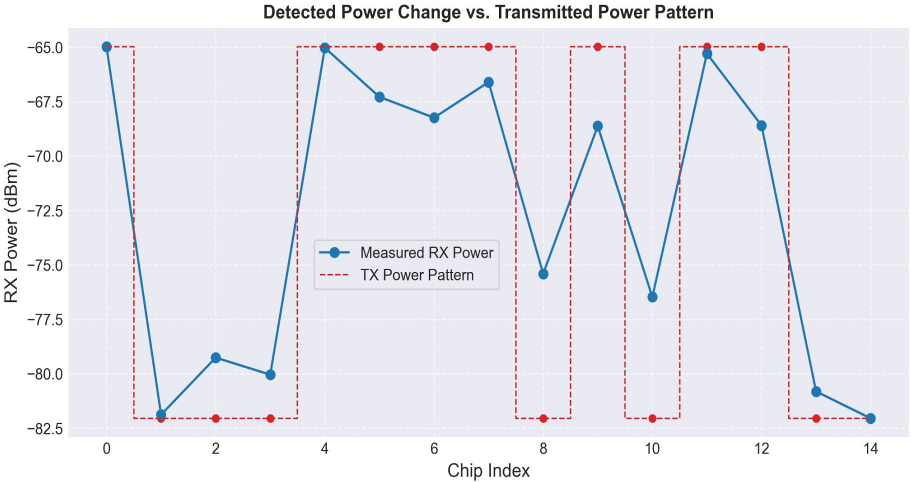
- Dynamic spectrum access enables use of underused bands and fast follow-ups
- Monitoring systems detect RFI but have limited sensitivity
- Telescopes are better suited to pinpoint RFI sources

Pseudonym Extraction Pipeline

- Telescope data: dynamic spectra, not ideal for signal ID
- I/Q data too heavy for wide bandwidths
- New pipeline extracts signal pseudonyms from spectra in real time

RFI Identification From Spectrogram Data

Experiment Setup



Initial Results

Location: Outdoor antenna array with parabolic dishes.
Transmitter: Laptop + SDR device used to generate controlled power change patterns.
Receiver: Large radio telescope dishes captured the transmitted signals.
Measurement: Spectrogram data was collected to detect changes corresponding to transmitted patterns.

Blue line & circles: Detected RX power changes.
Red dashed line: Expected transmitted power change pattern.
Observation: High-power chip align with RX power peaks. Low-power chip align with RX valleys.
Conclusion: The received power change patterns match the transmitted sequence, validating successful detection and synchronization in a real-world setting.