ORBIT Emulation and Machine Learning for Enabling 5G and Satellite Network Coexistence in the FR3 Spectrum

Aadhil Anvar, Christos A. Bovolis, Aman Grandhi, Parth Karekar
Advisors: Narayan B. Mandayam, Ivan Seskar, Sreeram Mandava

Intro

Aman Grandhi:

- Rising sophomore at Rutgers
- Studying EE + CS

Parth Karekar:

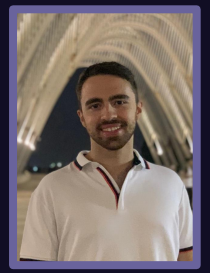
- Rising senior at Rutgers
- Studying EE

Aadhil Anvar:

- Graduate Student at Rutgers
- Studying ECE

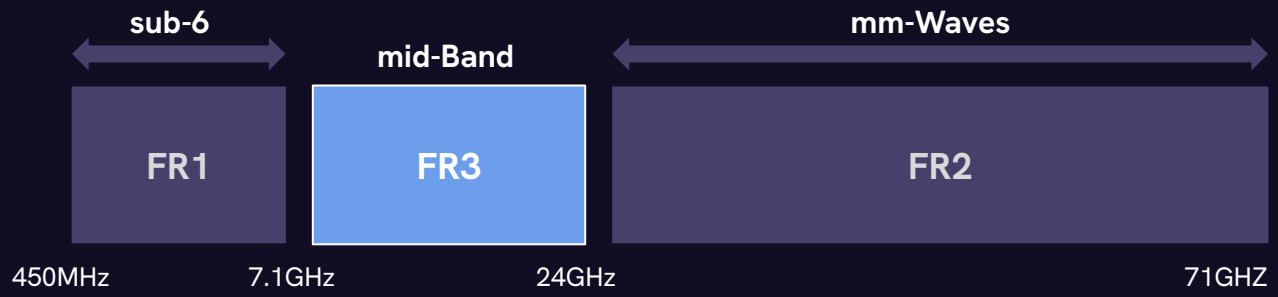
Christos A. Bovolis:

- Student at NTUA
- Studying ECE

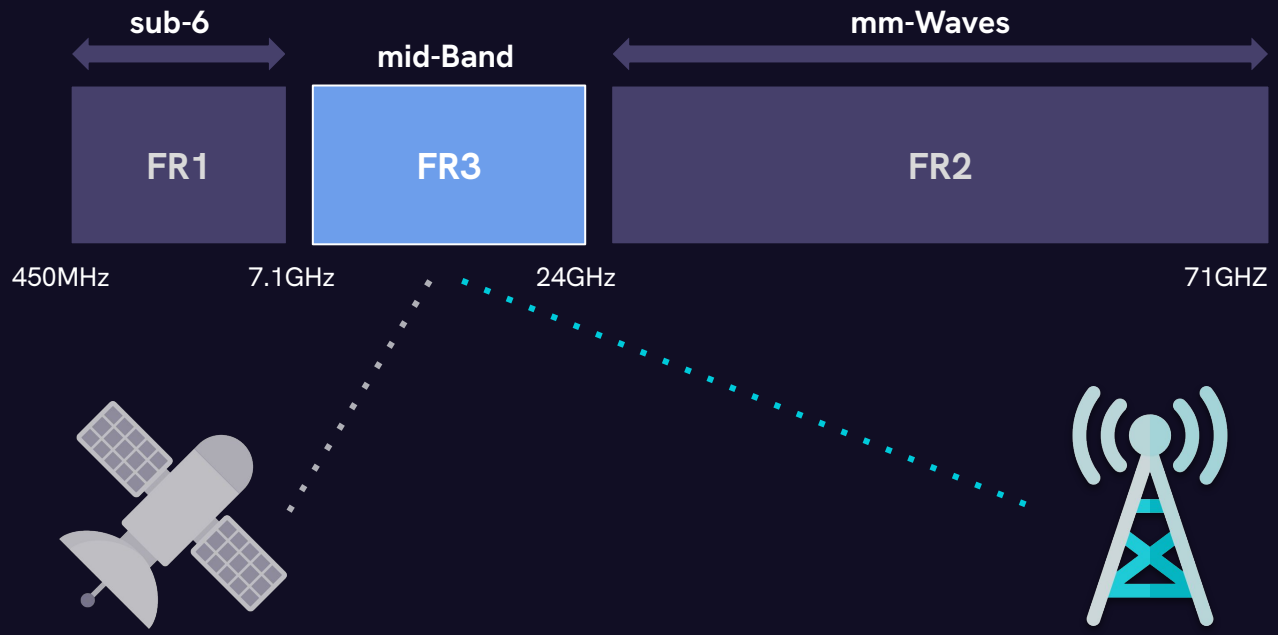


1) Problem Definition

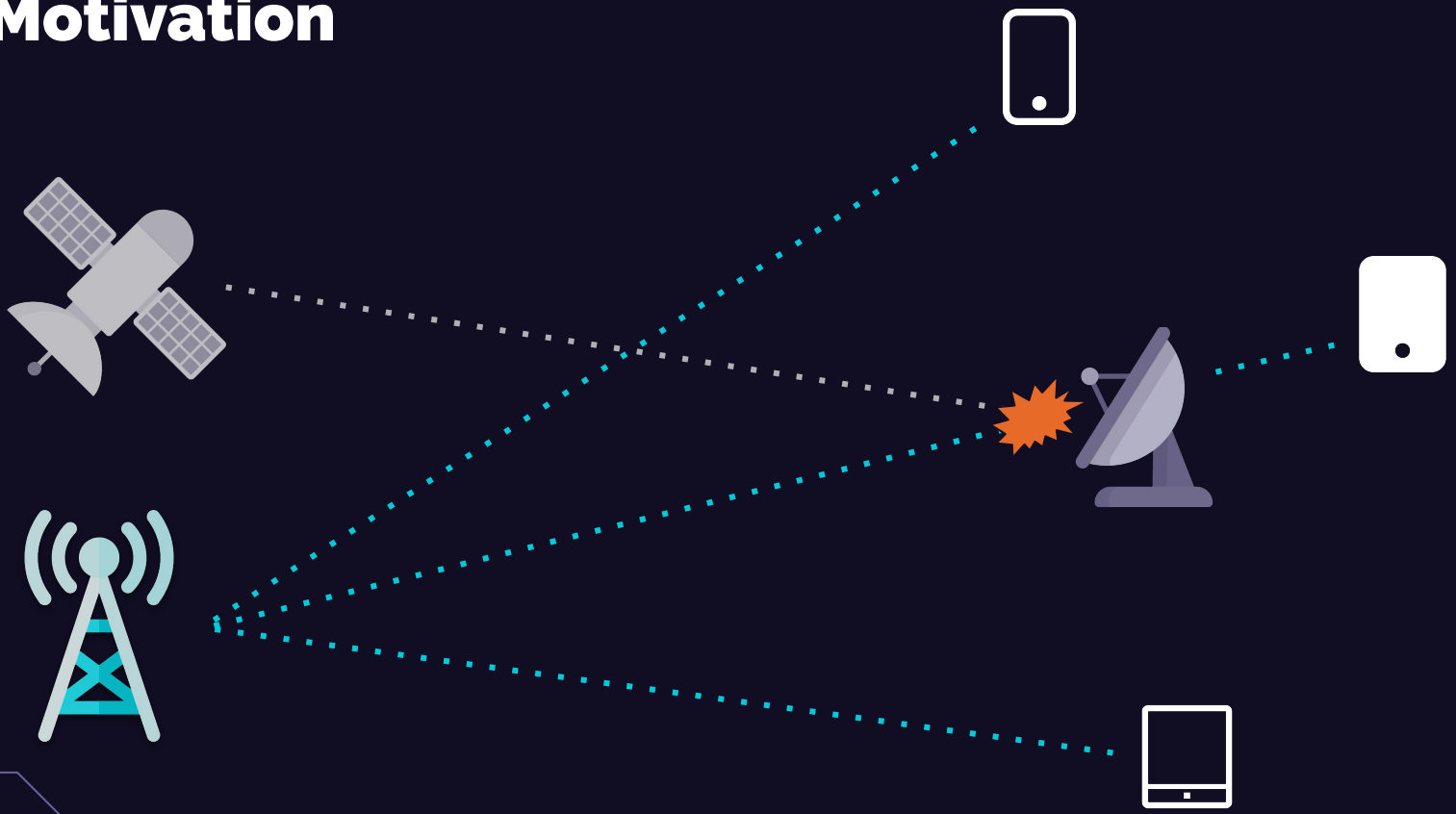
FR3



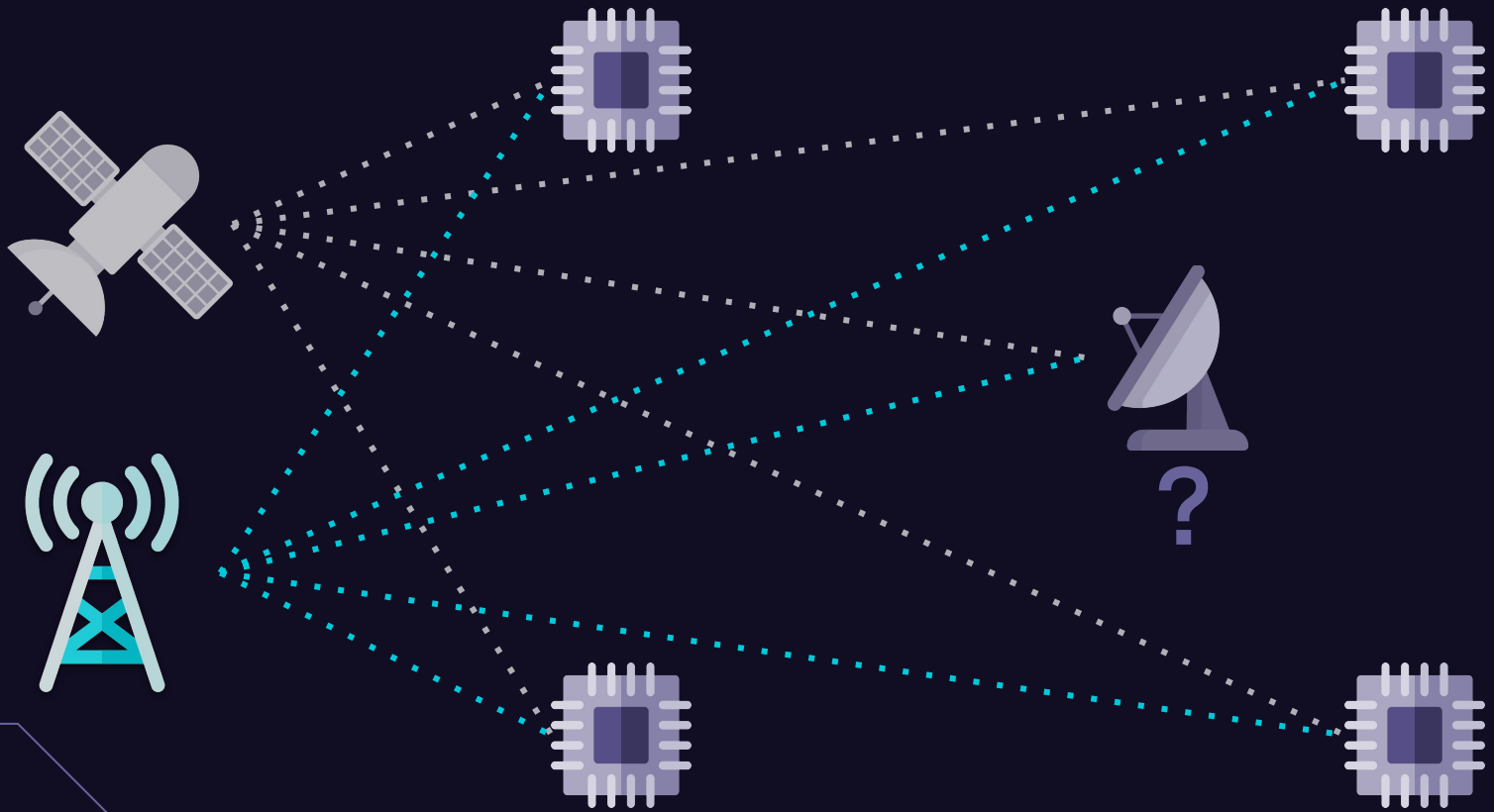
FR3



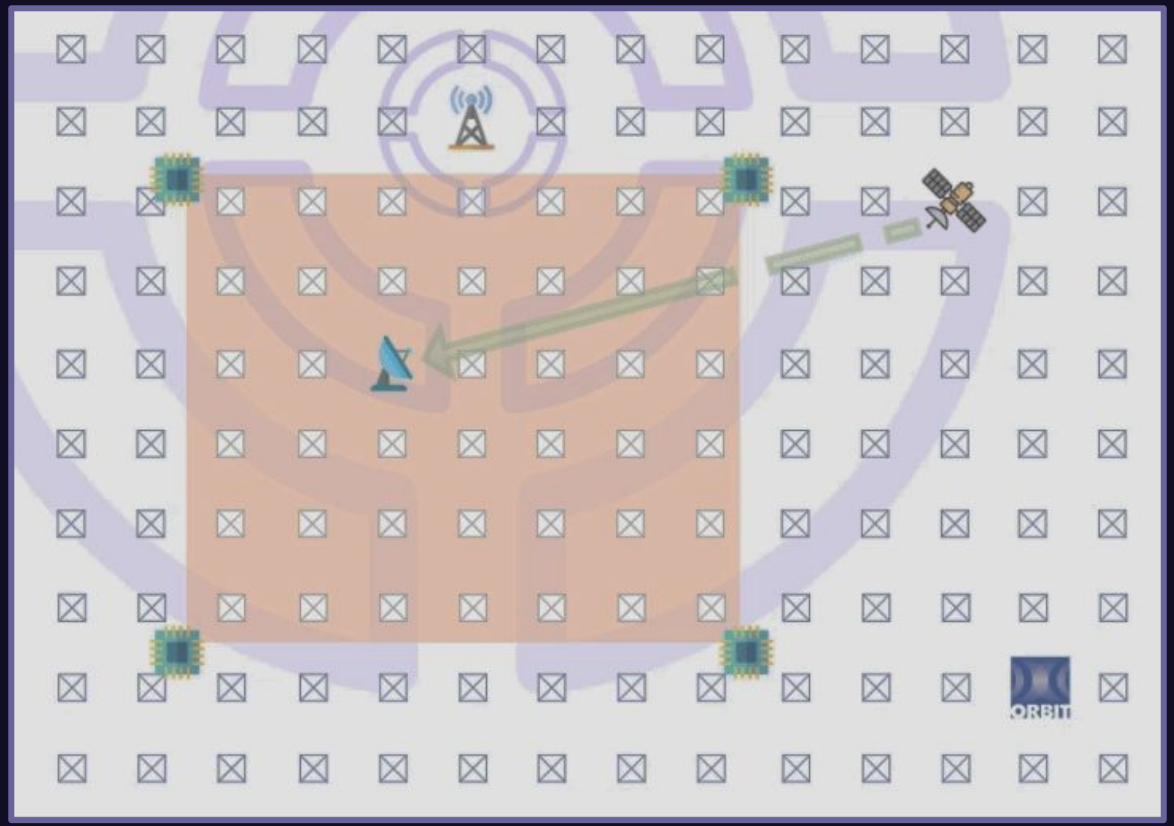
Motivation



Our approach

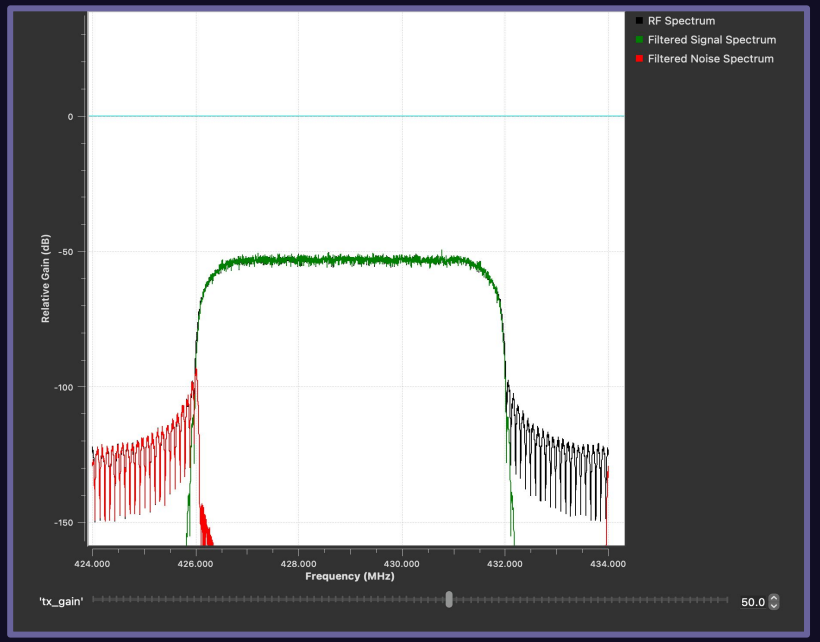


Topology

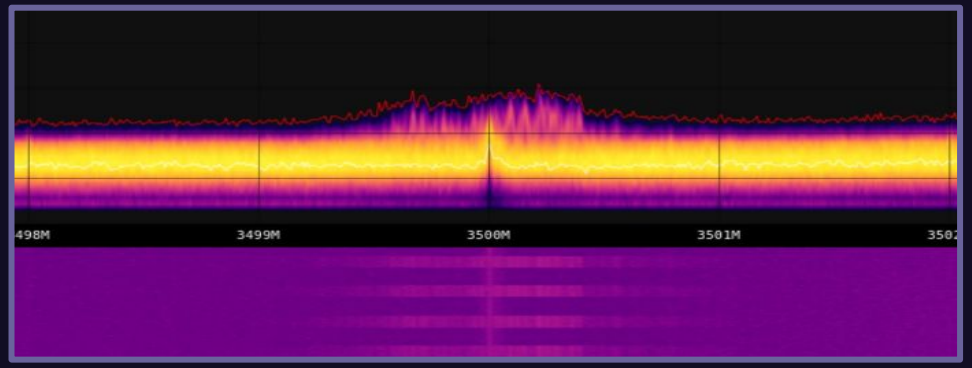


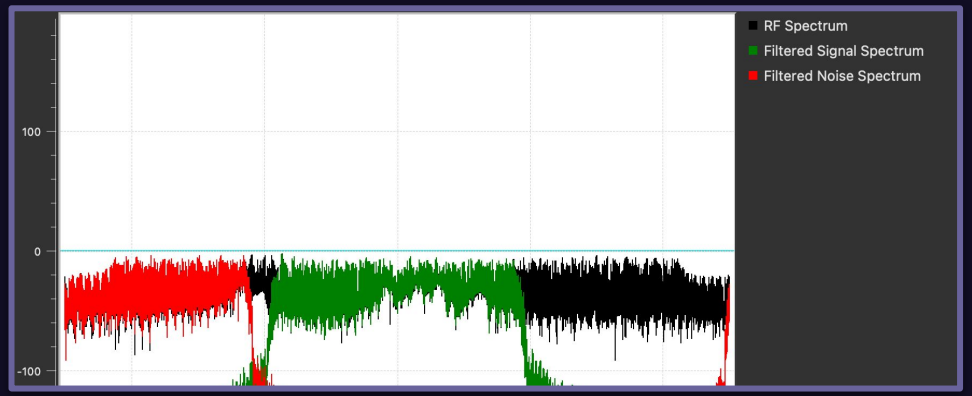
2) GNU Radio Implementations

Simulated satellite transmitter

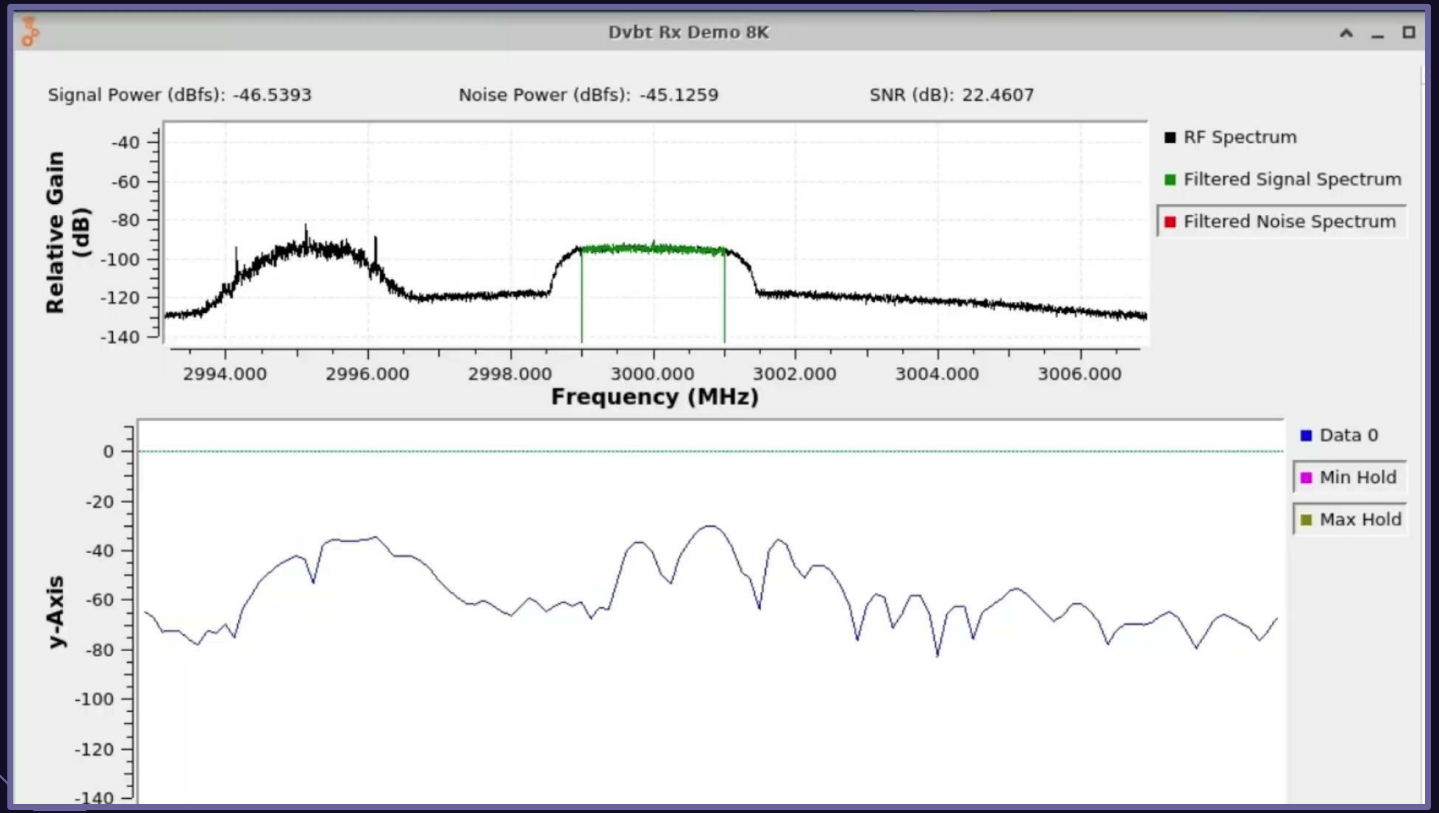


5G cell signal transmitter



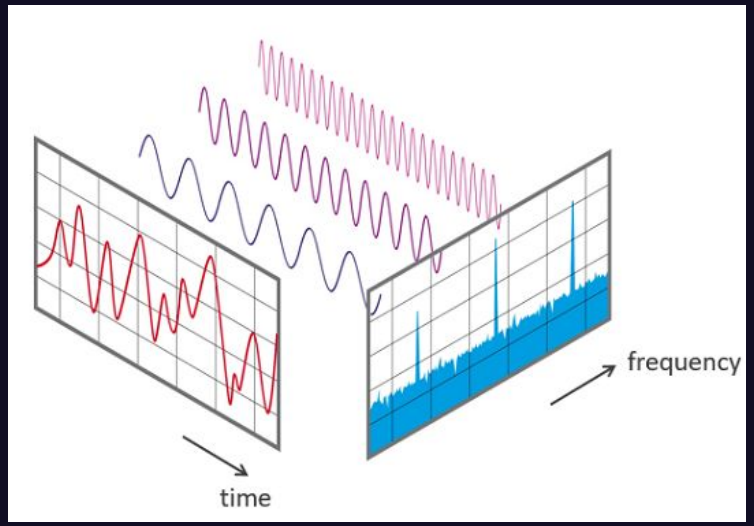


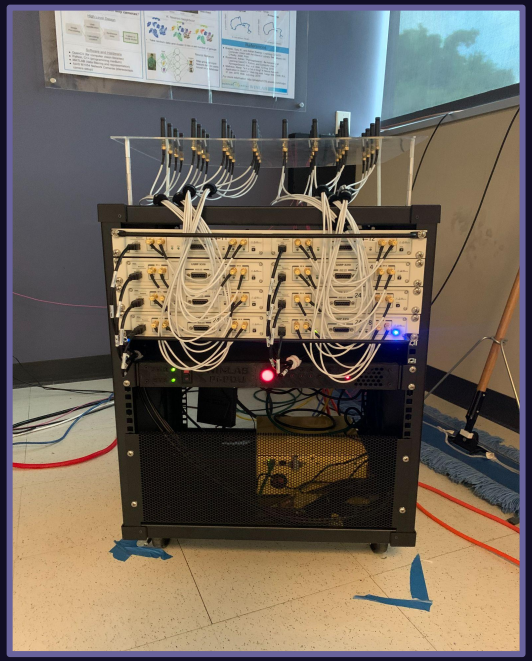
Signal Overlap



Measurement SDRs

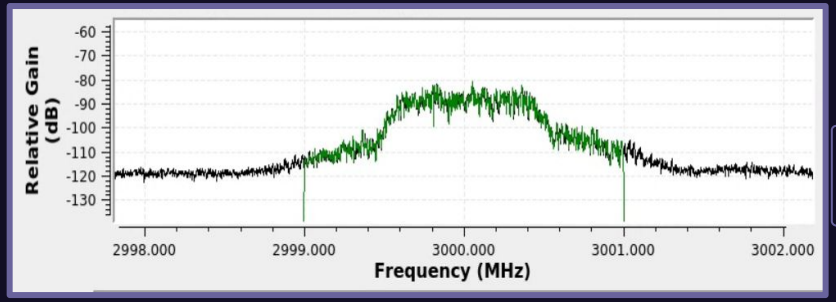
FFT Data

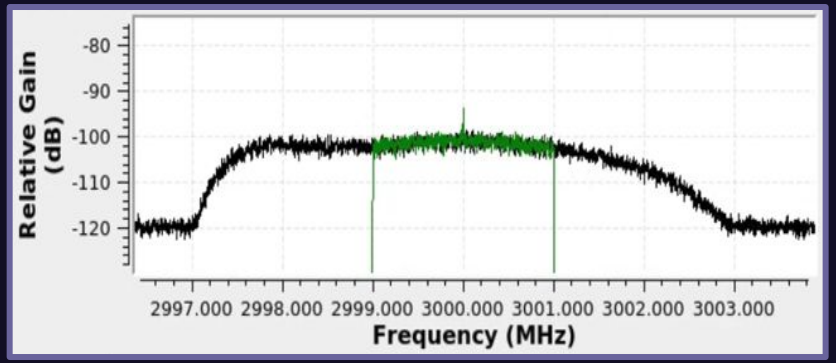




SINR Calculator

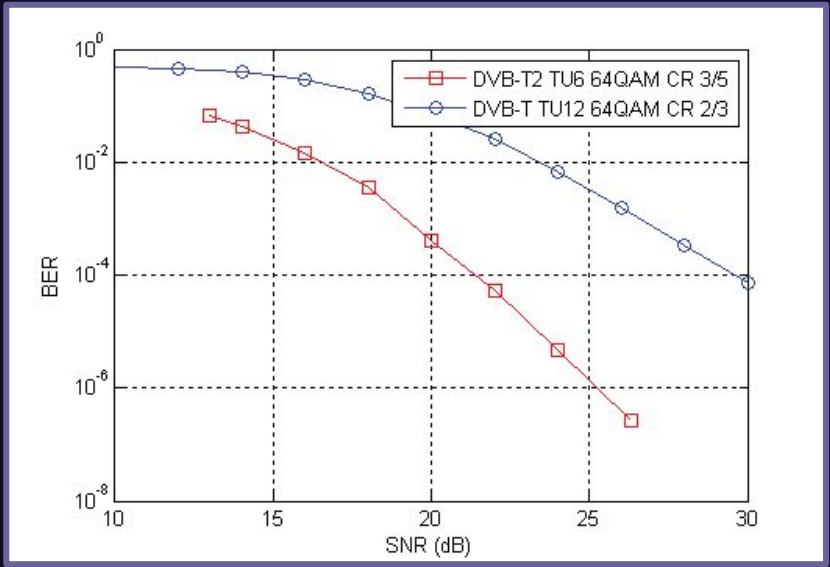
$$SINR = \frac{S}{I + N}$$





Performance Metrics

$$\text{Bit Error Rate, BER} = \frac{\text{Number of errors}}{\text{Total number of bits sent}}$$

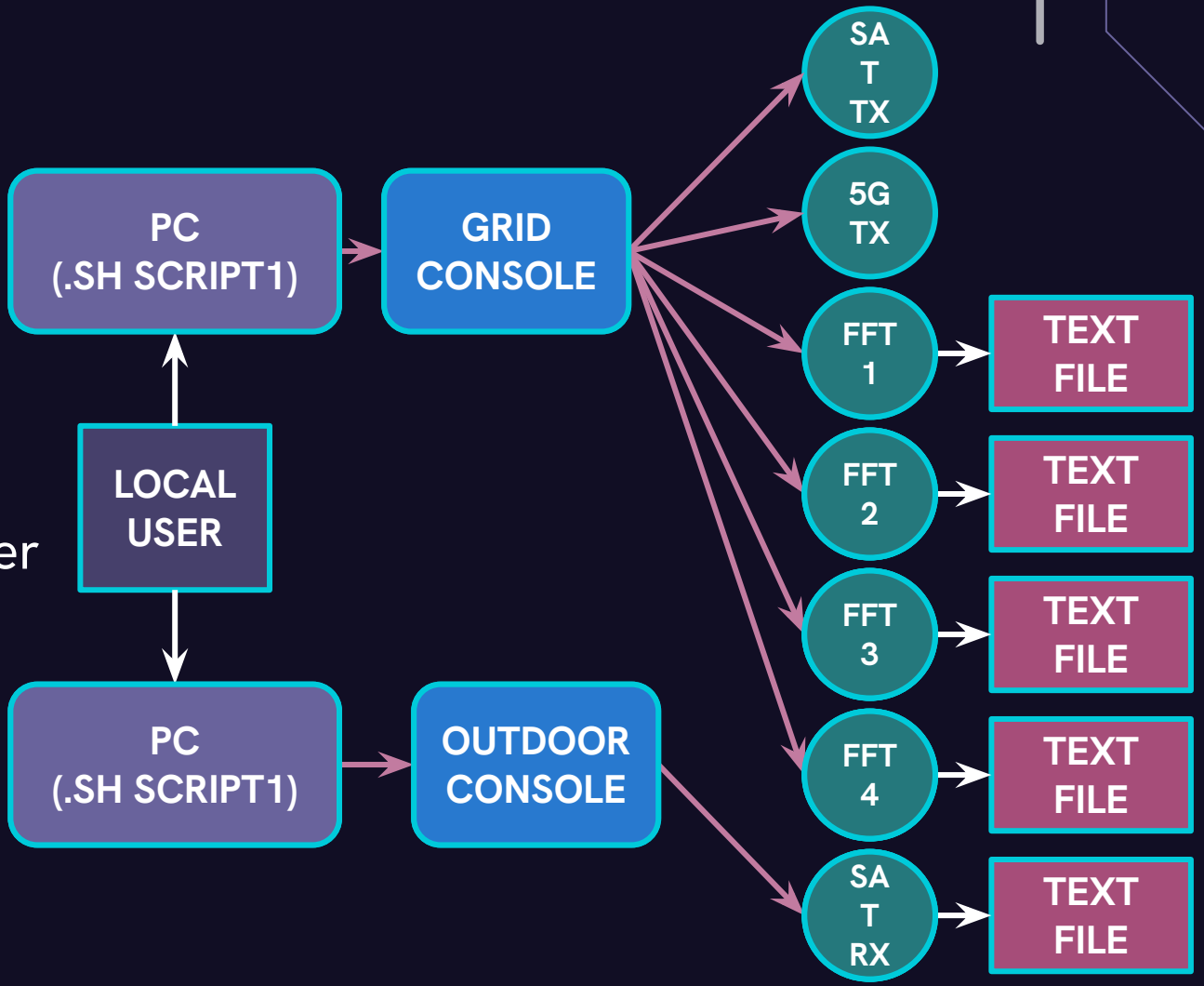


3) ORBIT Experiment

Setup

Parameters:

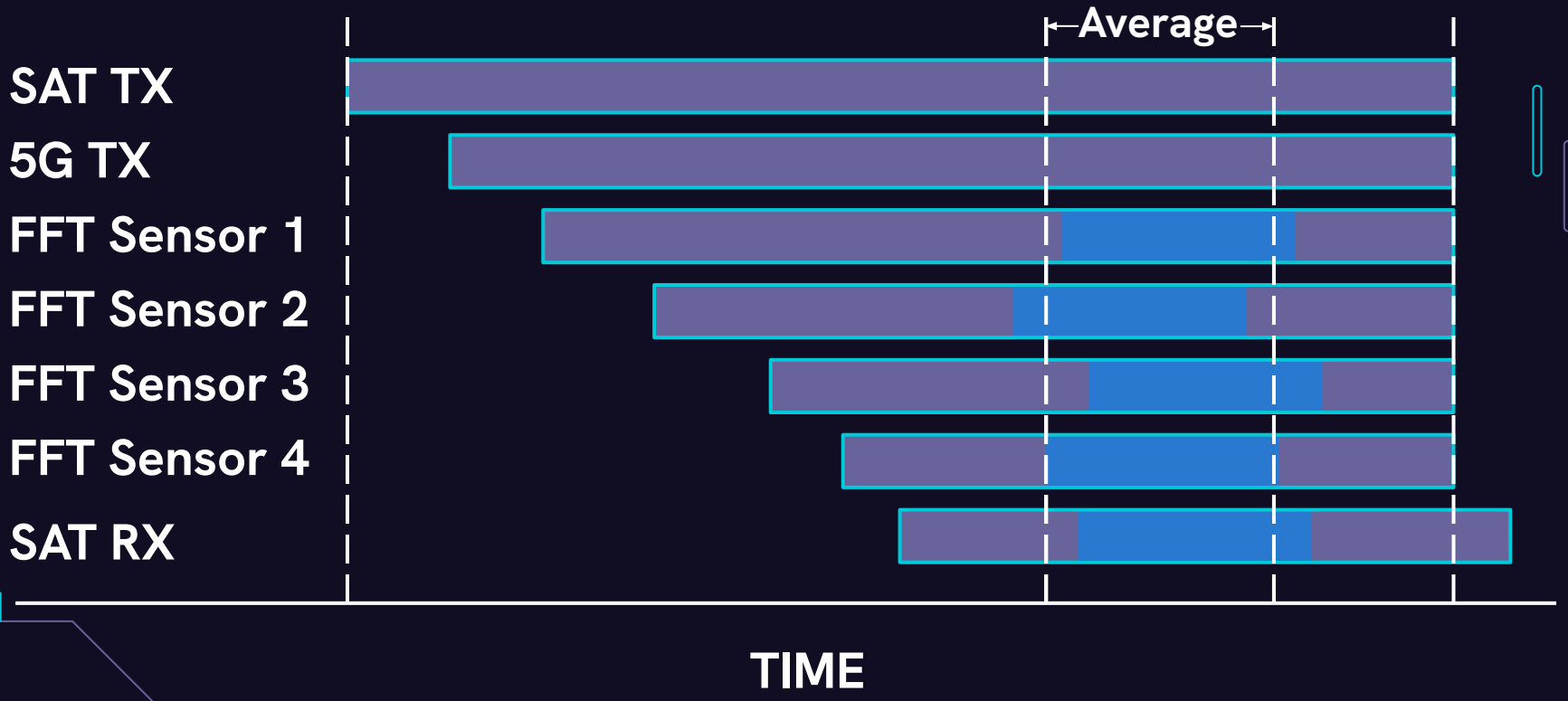
- 5G Center Frequency
- 5G Transmitter Gain



→ via SSH

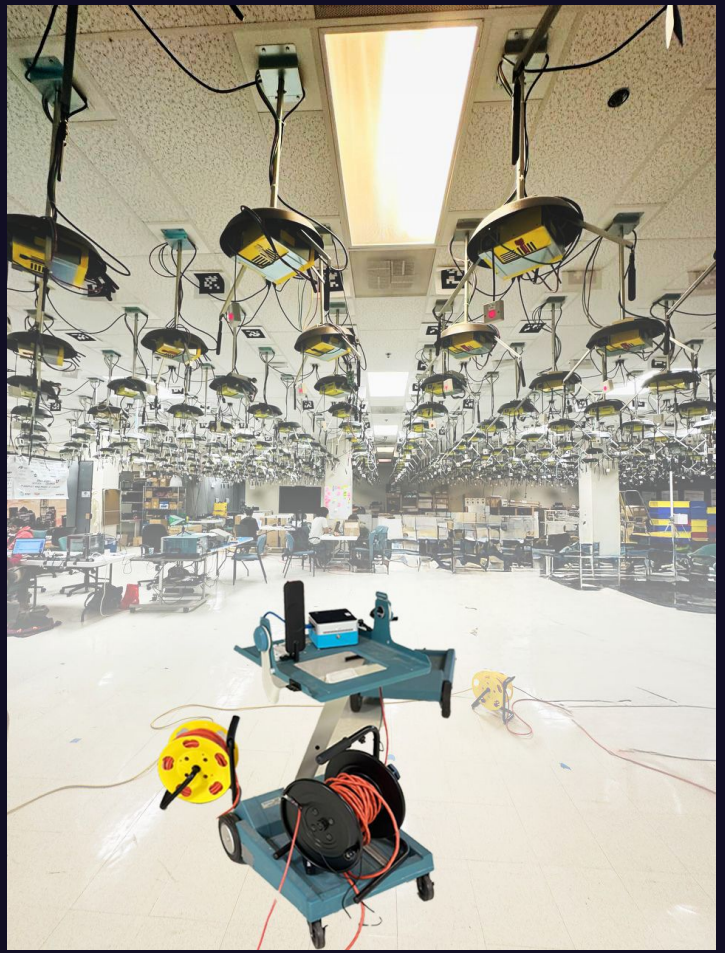
→ via BASH

Time Diagram



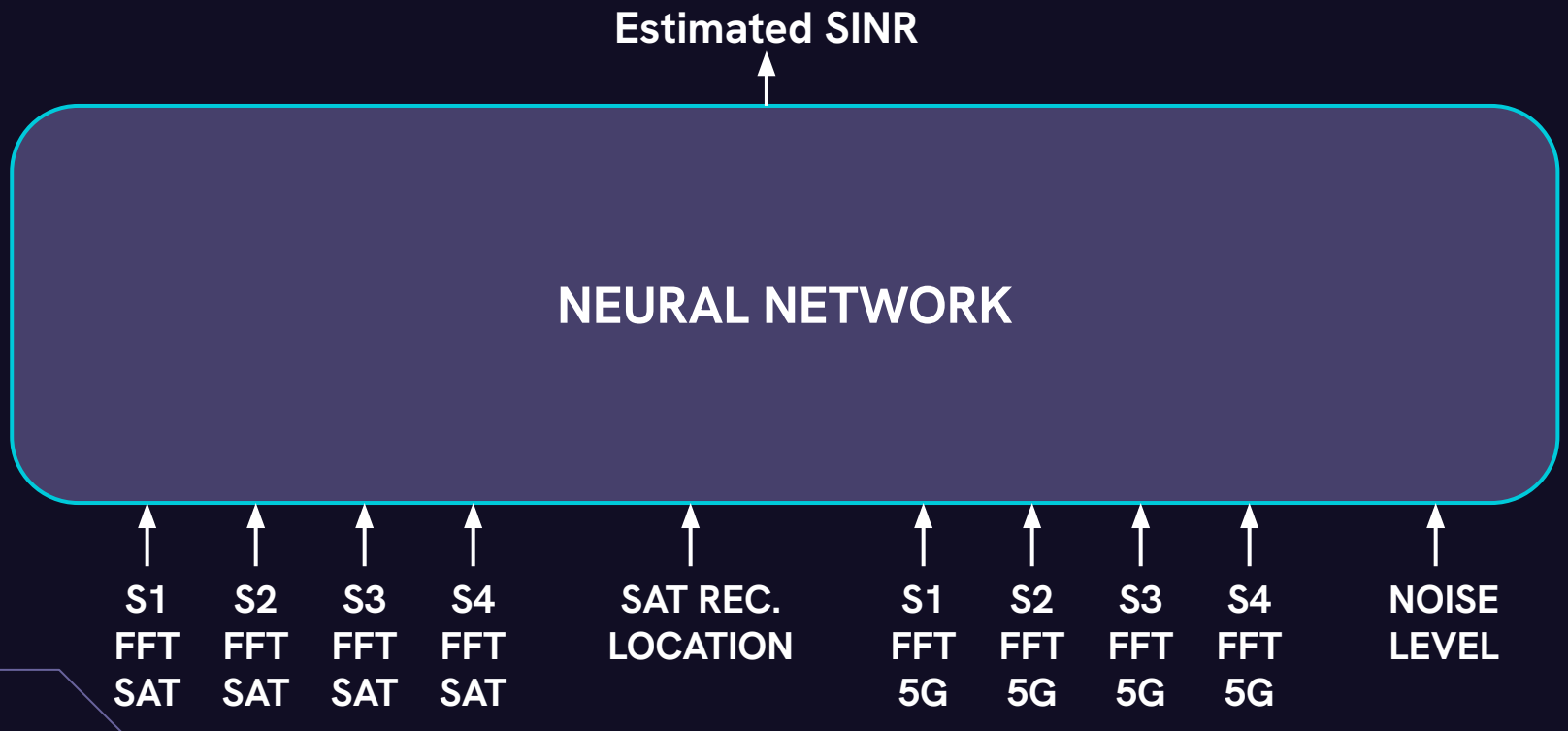
Experiments

- 3000 measurements
- 15 locations

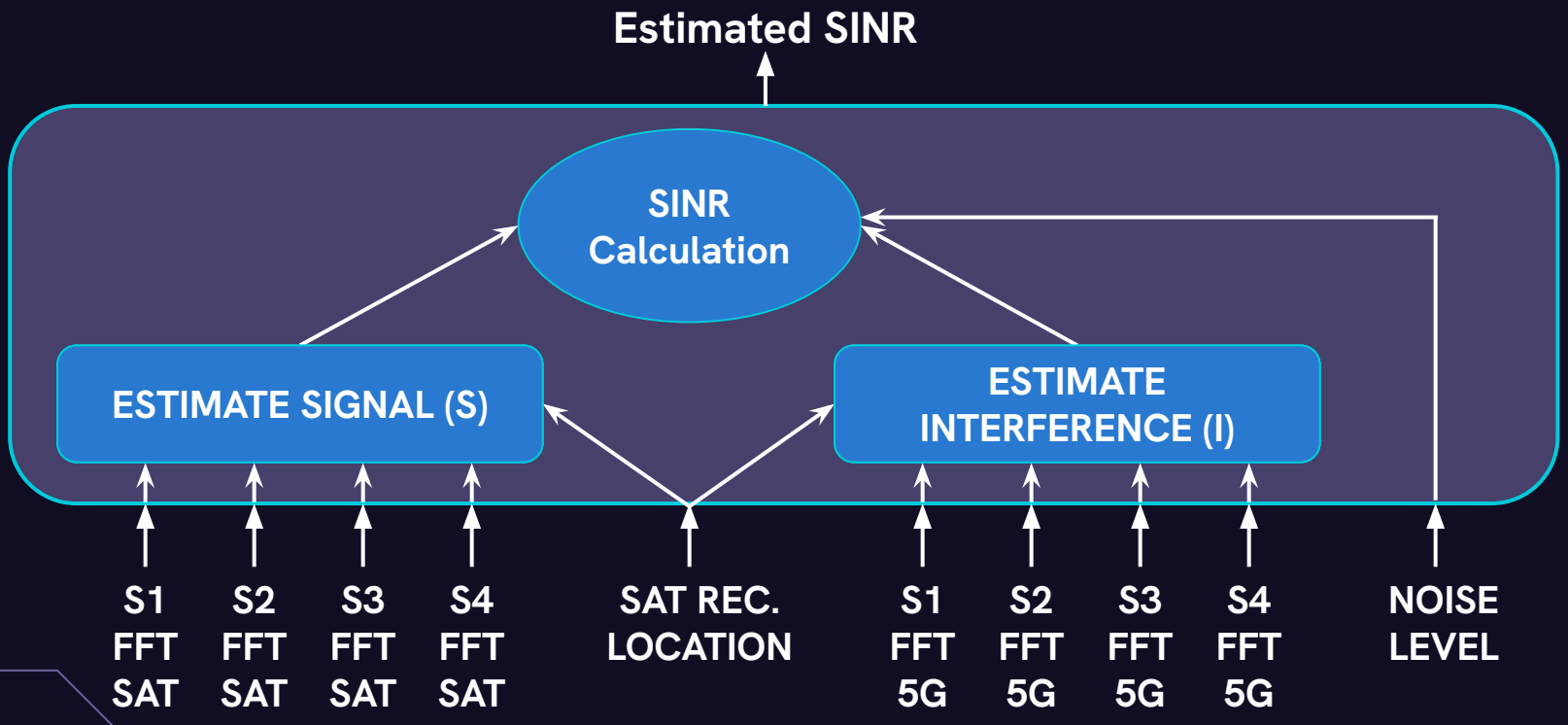


4) Machine Learning Model

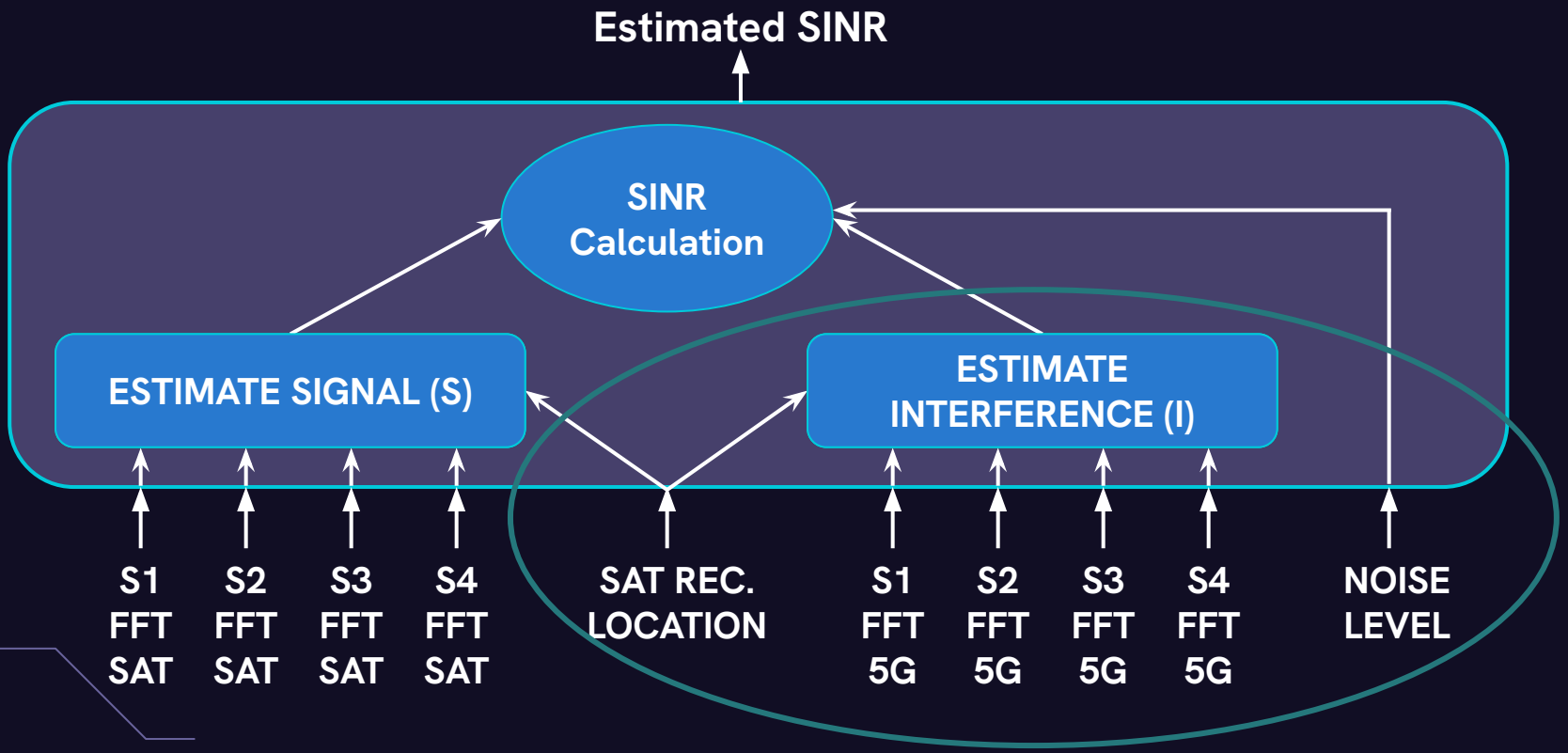
Neural Network as a Black Box



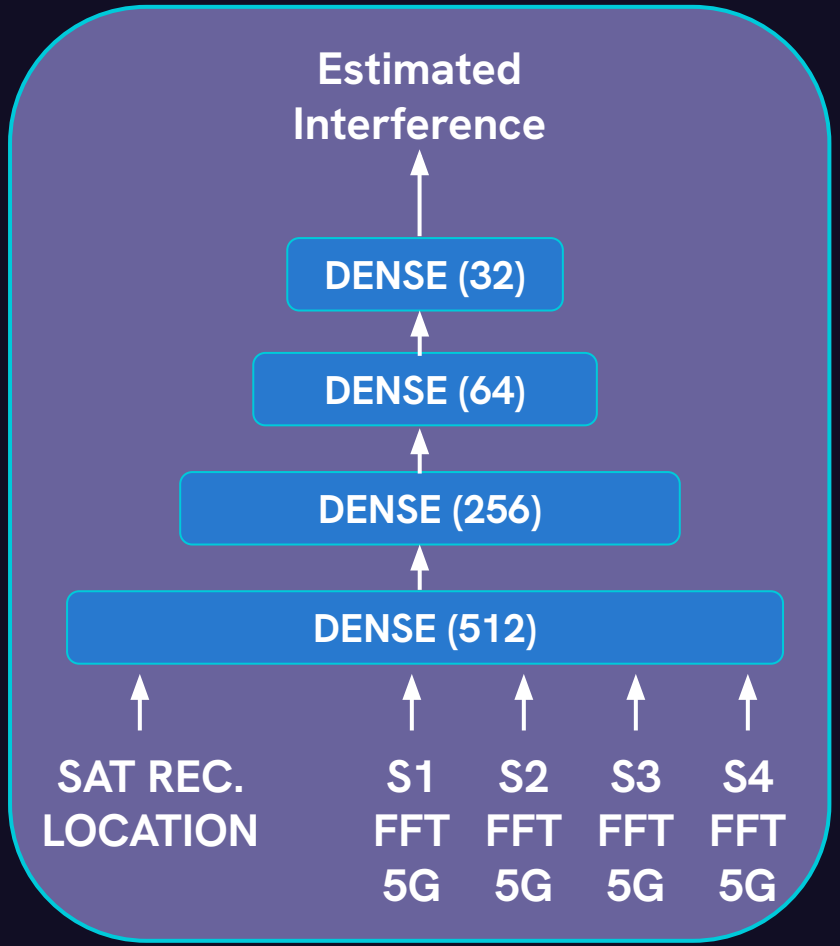
Simplifying the Neural Network



Simplifying the Neural Network



Universal Signal Power Estimator



5) Data Preprocessing

A possible issue

- Dataset includes spatial coordinates as features,
  - represented as location codes: (e.g. 1_1, 1_2, ..., 2_1, 2_2).
- Data Collection limited to **few** locations.
- Model incorrectly interprets these locations as **distinct classes**.

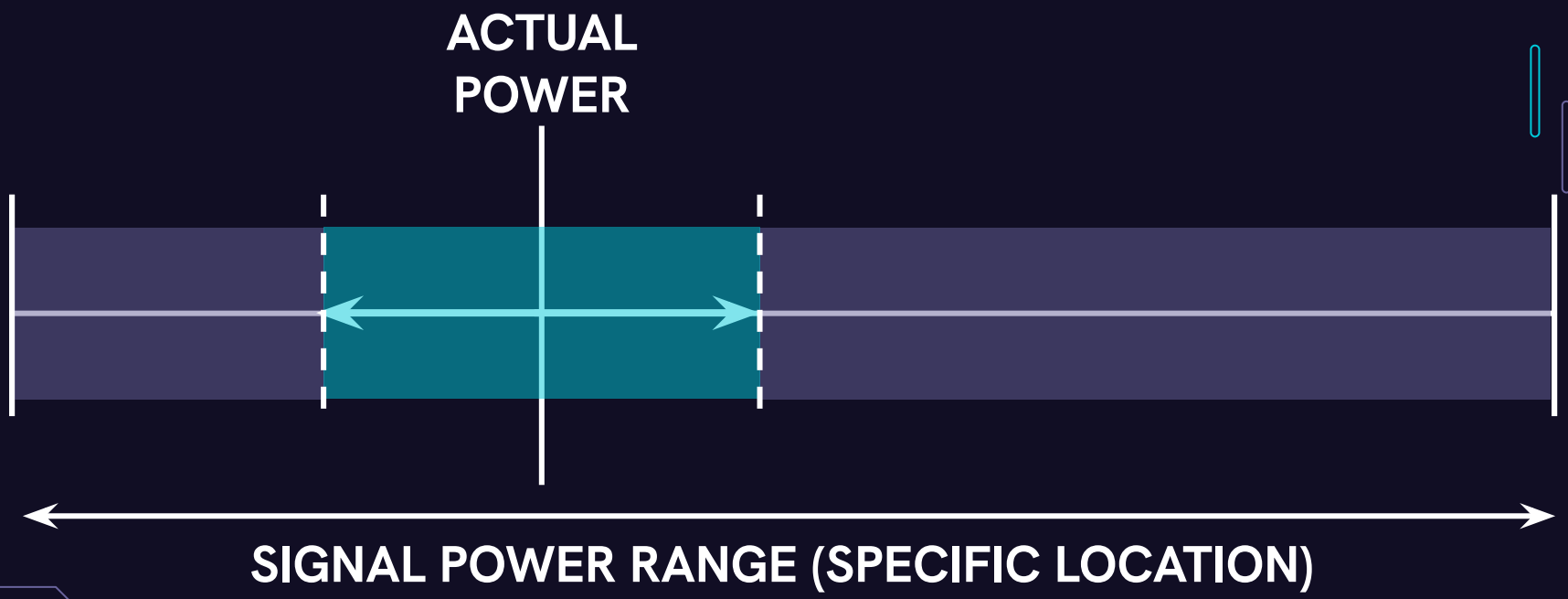
Noise Injection

- Introduce **small random variations** to location coordinates
- Encourages treating location coordinates in continuous form
- Combats overfitting

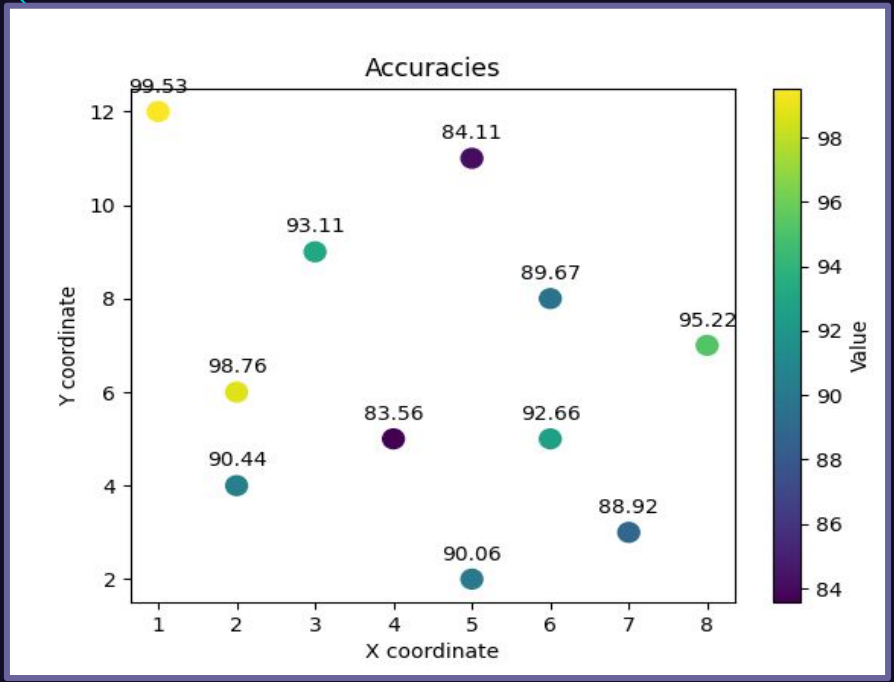
4 => 3.99, 4.03, 4.11

6) Evaluation

Evaluation Metric



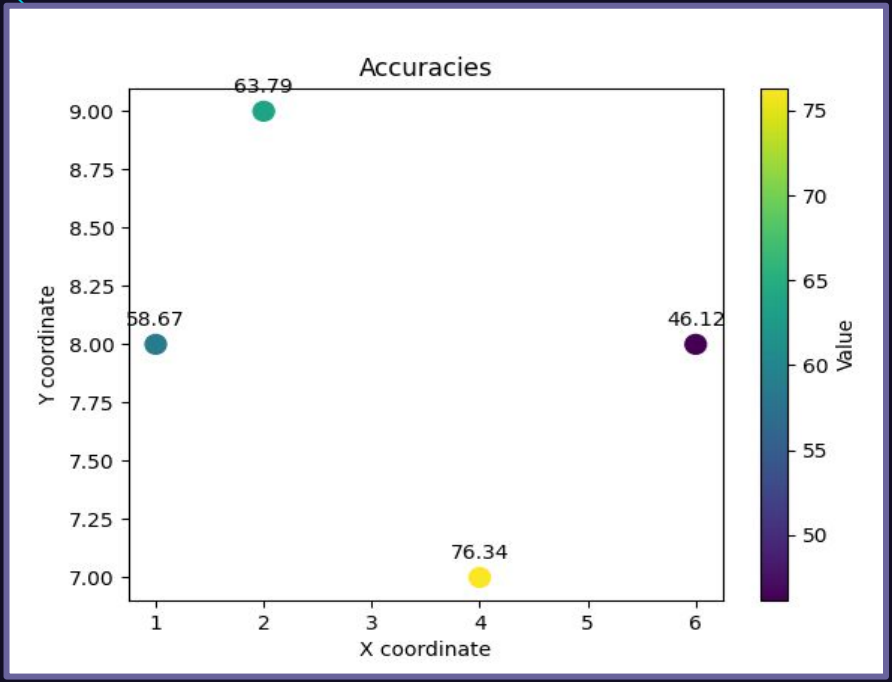
Accuracy in Known Locations



Train: **80%** Test: **20%**

Average accuracy: **91.44%**
Pretty Good!

Accuracy in Unknown Locations



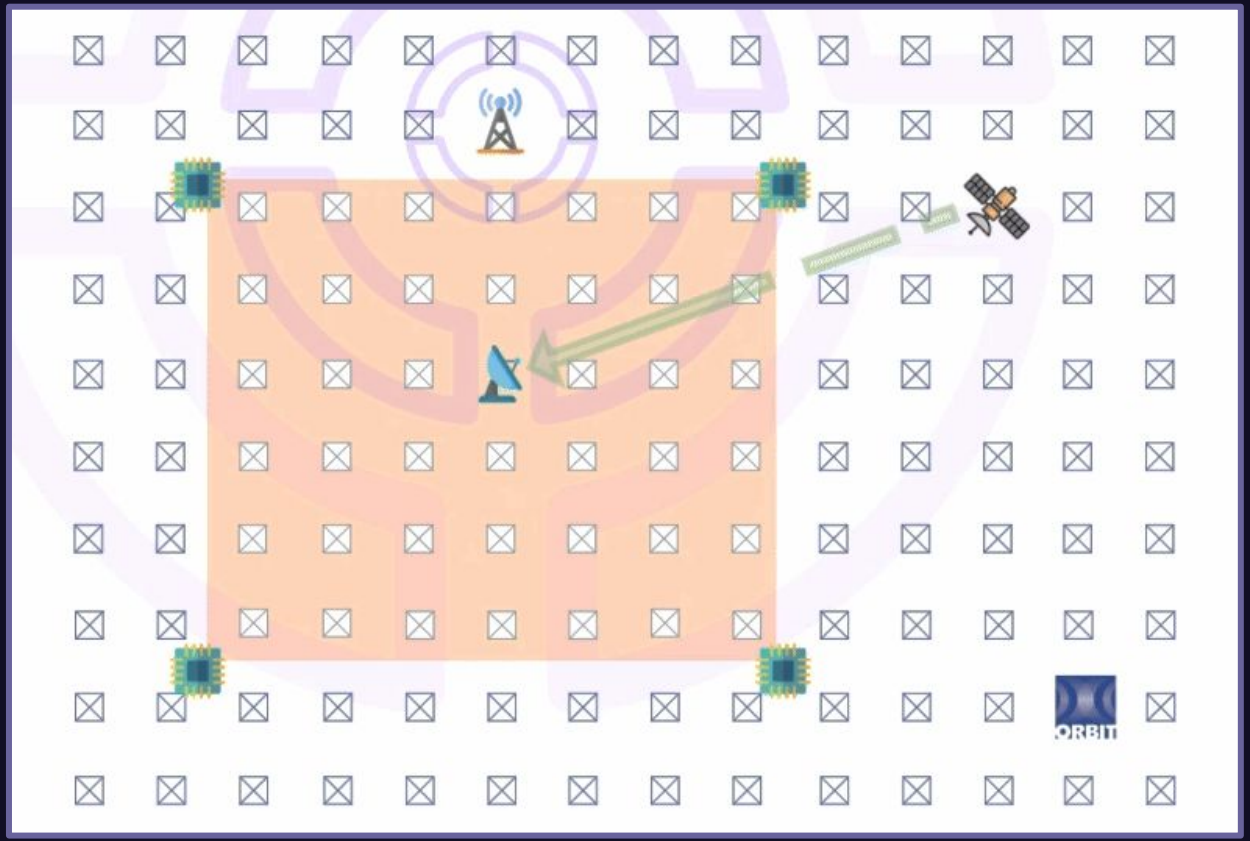
Average accuracy: **61.23%**
Location granularity is not enough!

7) Conclusion

Conclusion

- Neural networks reliably estimate interference (4 fixed FFT sensors)
- High accuracy for known locations
- Sparse training lacks spatial awareness
- Dense measurements could enable a universal estimator

Future Work



Thank You!