Software-defined mmWave Initial Access using GNU Radio

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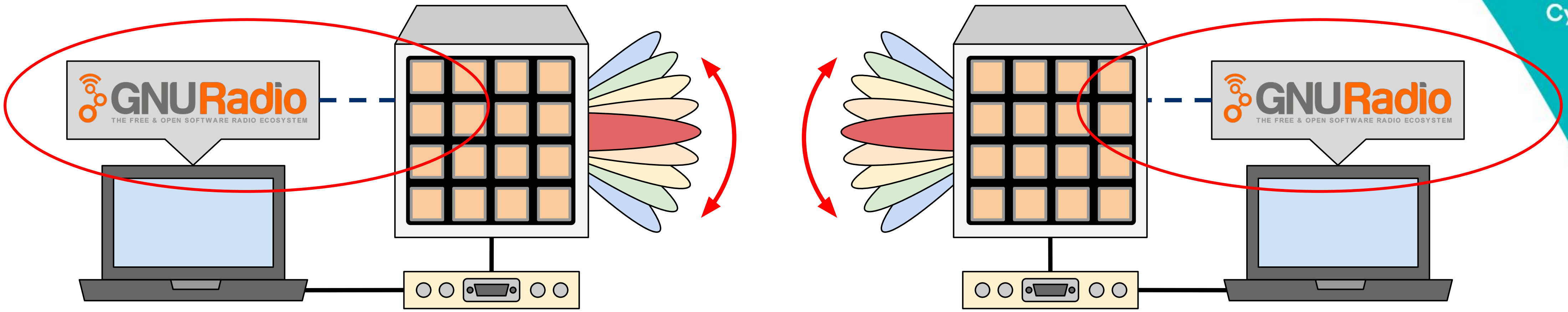
Commonwealth Cyber Initiative | Virginia Tech

GNU Radio Conference, September 28th, 2022

Our Contribution



- **Expose control** of mmWave front-ends in GNU Radio
- Implement a flexible **initial access control loop**
- **Enabling high-level experiments**, e.g., beam management & initial access design trade-offs

Outline

- Motivation
- Implementation
- Experimental Results
- Conclusions

OTA Experiments < 6GHz

(SISO, omnidirectional antennas)

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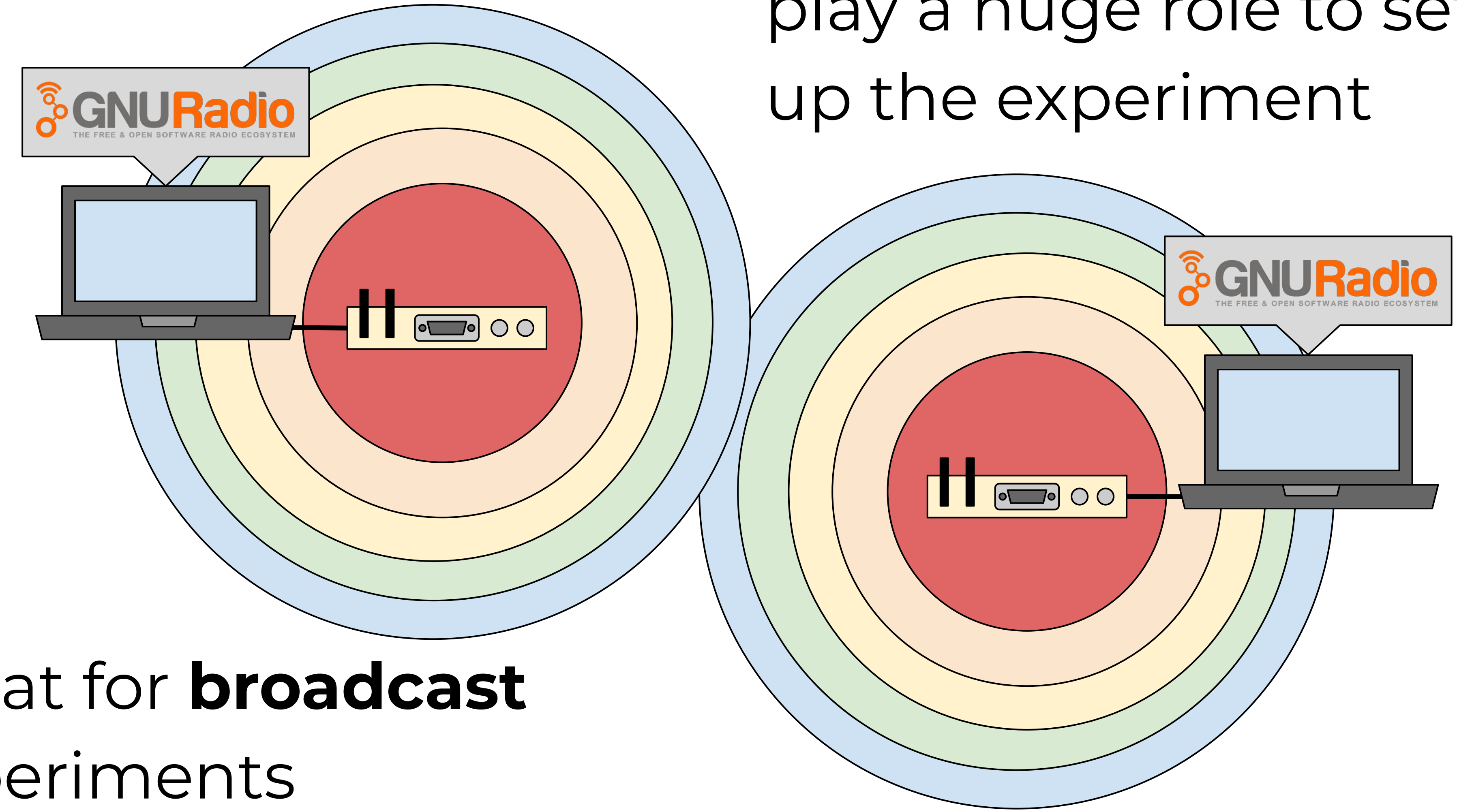
- **Distance** and **gain** play a huge role to set up the experiment



- Great for **broadcast** experiments

OTA Experiments > 6GHz

(using mmWave front-ends)

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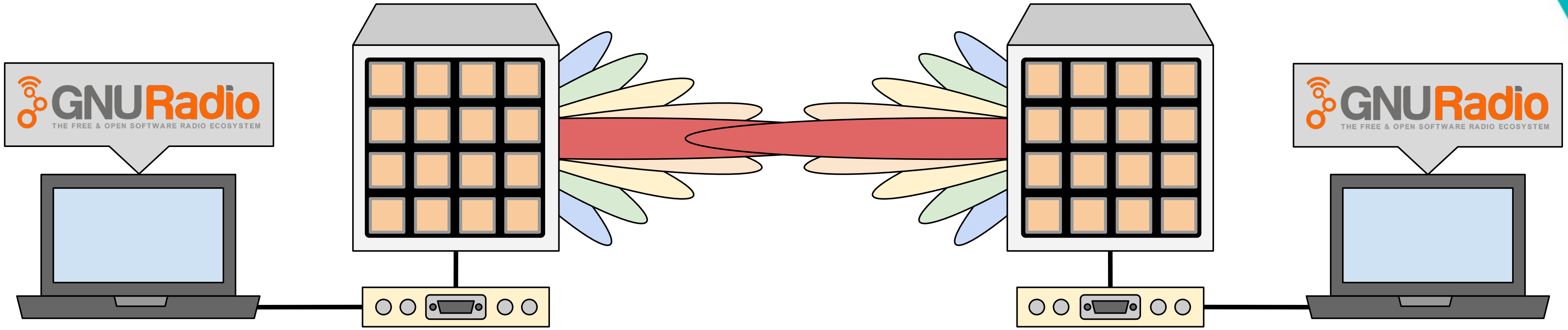

- Combine **flexibility** of SDRs with **directionality** of mmWave front-ends (InterDigital, Sivers, etc)
- Experiments **characterizing** equipment and medium

OTA Experiments > 6GHz

(using mmWave front-ends)

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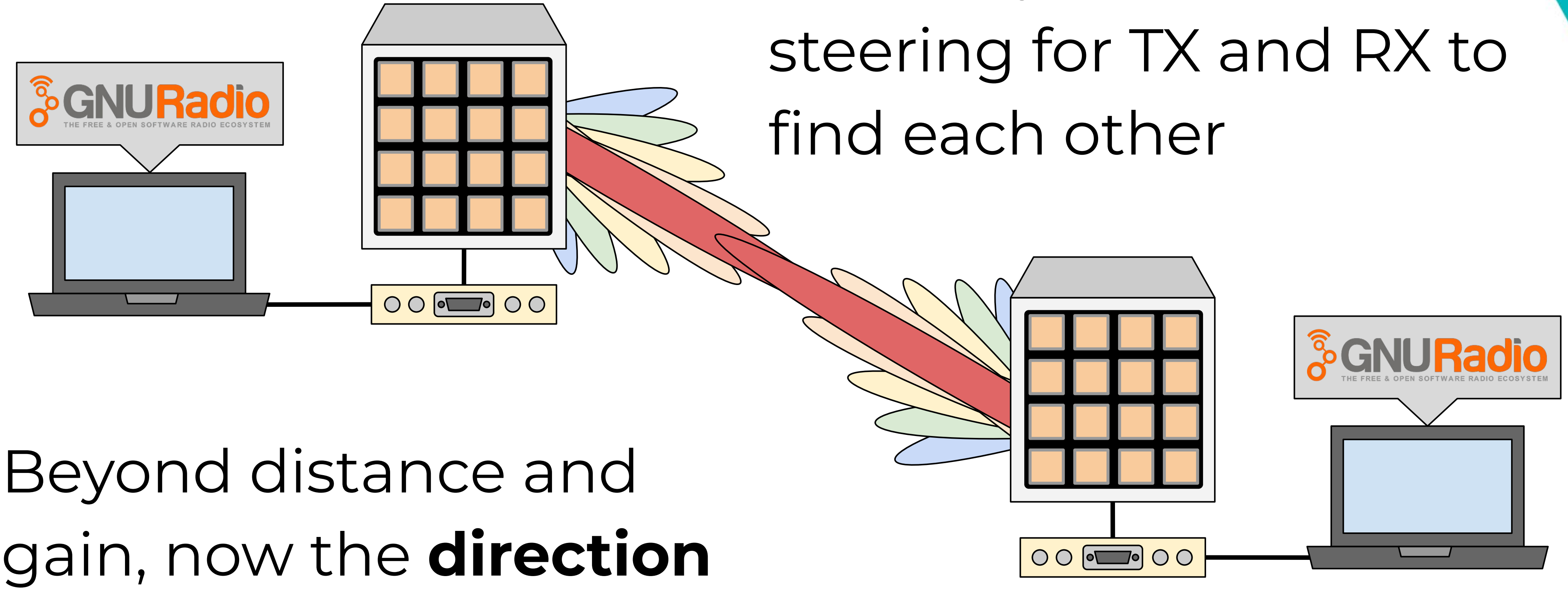
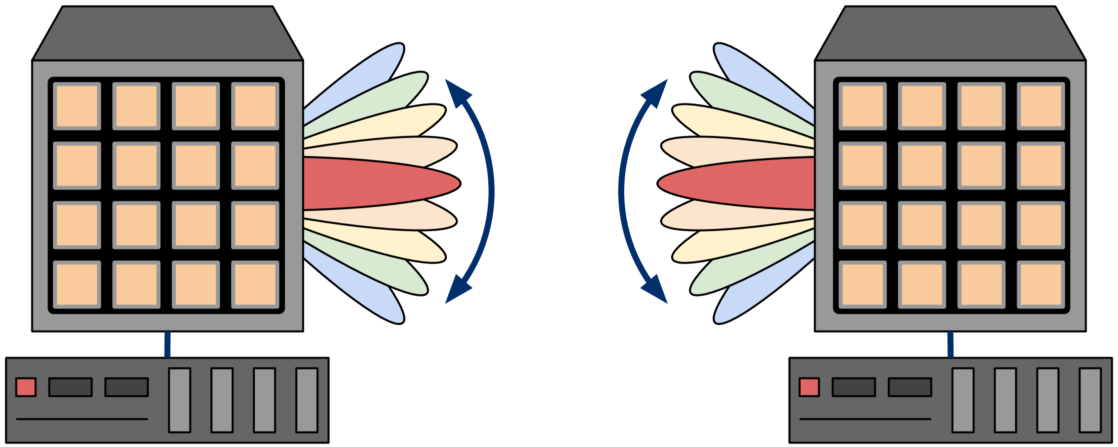
- Currently, **manual** beam steering for TX and RX to find each other



- Beyond distance and gain, now the **direction** also plays a huge role

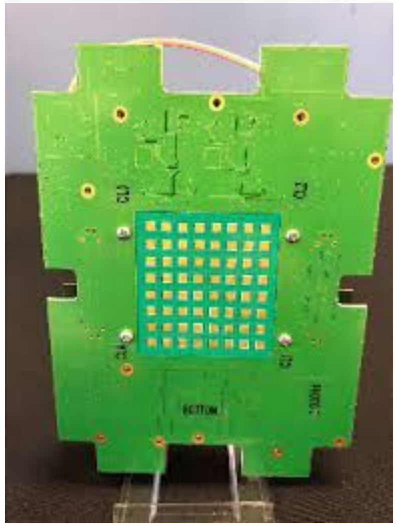
Initial Access Procedure

Locate TX and RX before establishing communication



- Manual beam steering may be **impractical**
- Initial access **dynamically locates** TX and RX
- Proving the environment to find the **best beams**
- **MAC-level functionality** missing from GNU Radio

Current mmWave Front-ends



InterDigital
MHU

Sivers
EVK

- Multi-element **phased-array antenna modules**
- RF chains for up/down converting from/to IF
- **Real-time control** over **GPIO** and/or SPI:
    - Transmission mode (TX, RX, TRX, off)
    - Gain (TX, RX)
    - Codebooks, a.k.a., beams (TX/RX direction)

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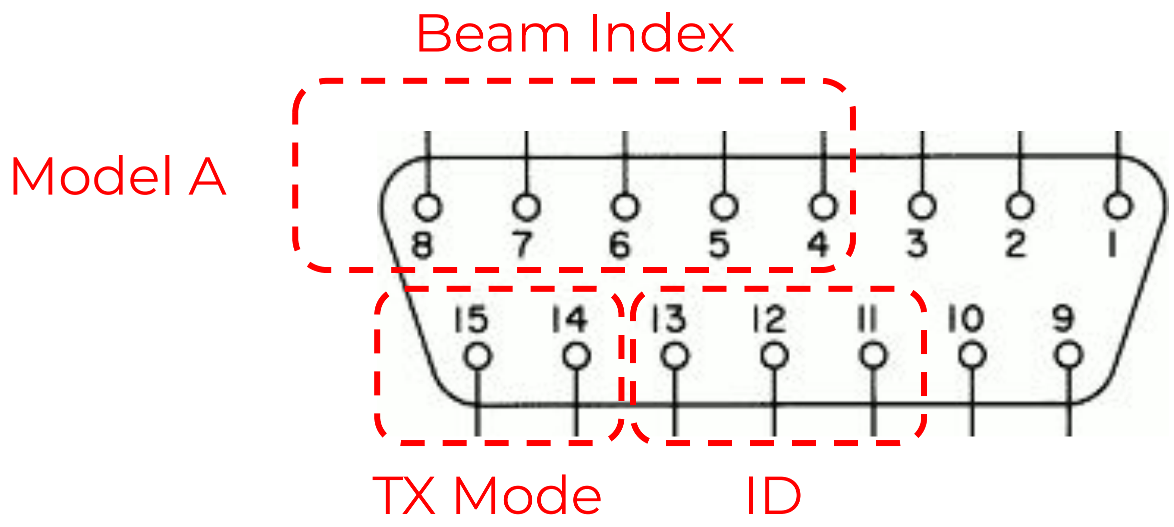
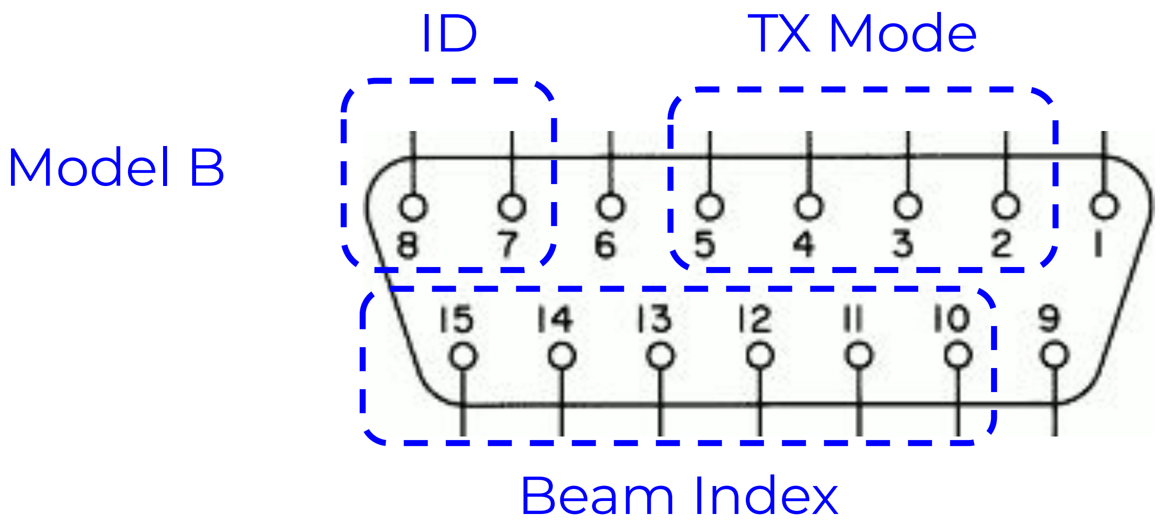
SofTwAre-defined Mmwave INitial Access (STAMINA)

Abstracting GPIO Control



- Different pins and ranges for the **same functionality**
- **Parameterization** to different models using config files
- Incorporating **hardware-specific** considerations
- Expose high-level abstraction as a **GNU Radio block**

Abstracting GPIO Control



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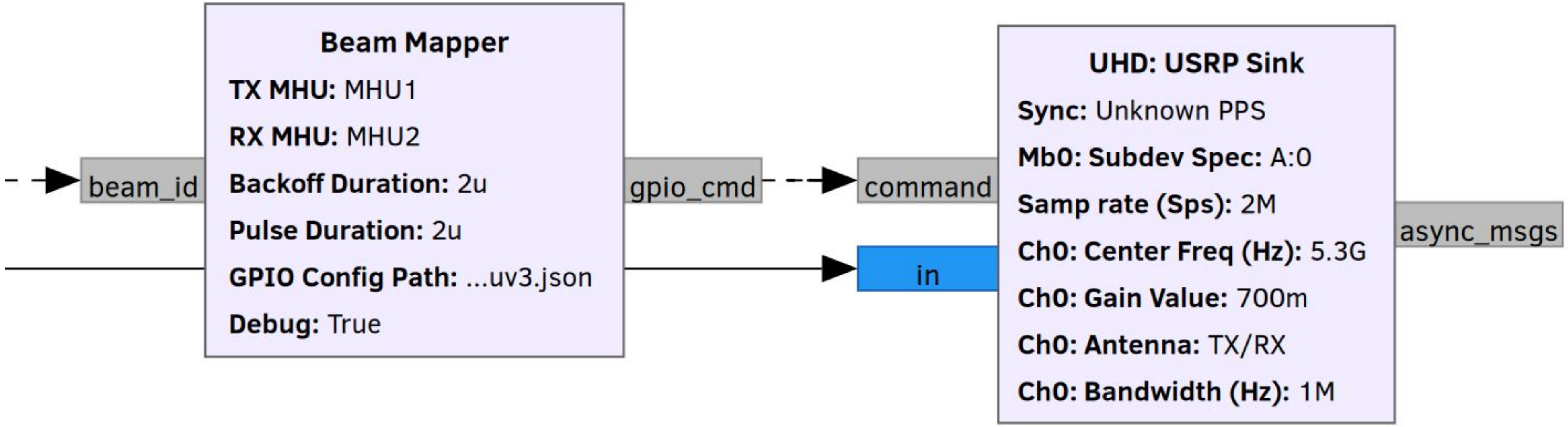

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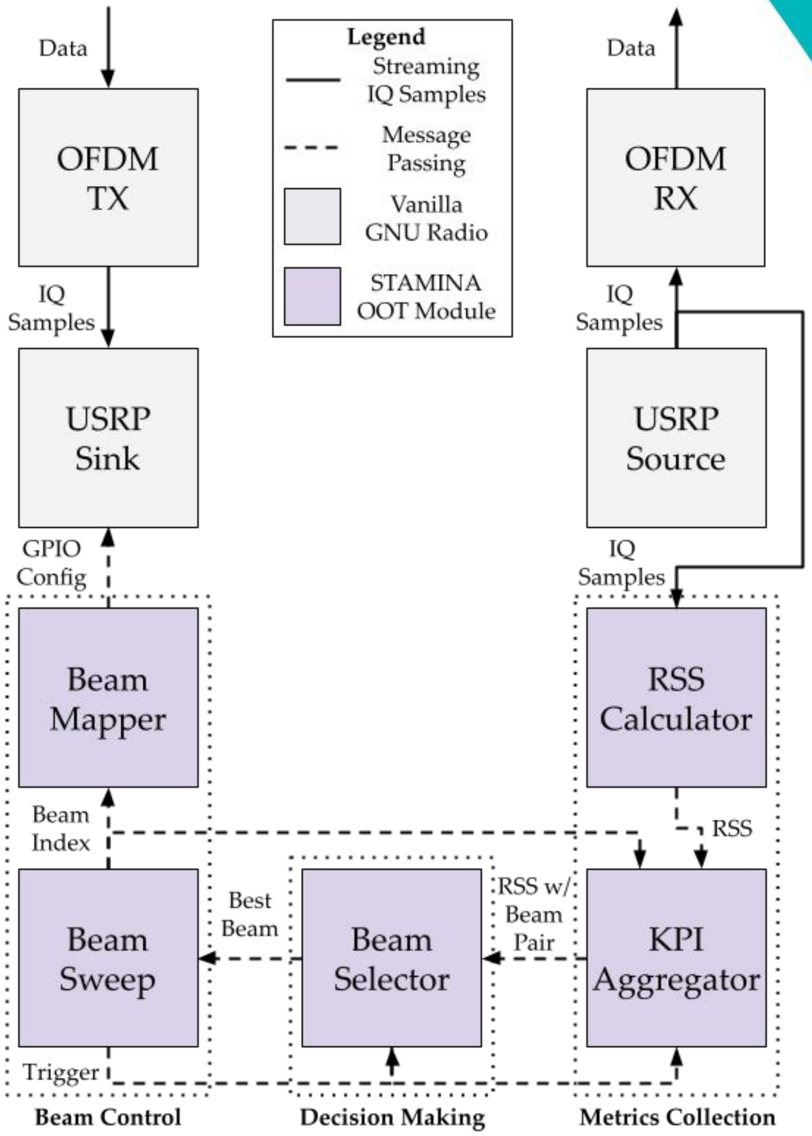
Initial Access Control Loop

- Iteratively **sweeping** over different beams
- Capturing the Received Signal Strength (RSS) from **different directions**
- Using the highest RSS to decide the **best beam pair** for data transmission
- Loop and adapt to changes



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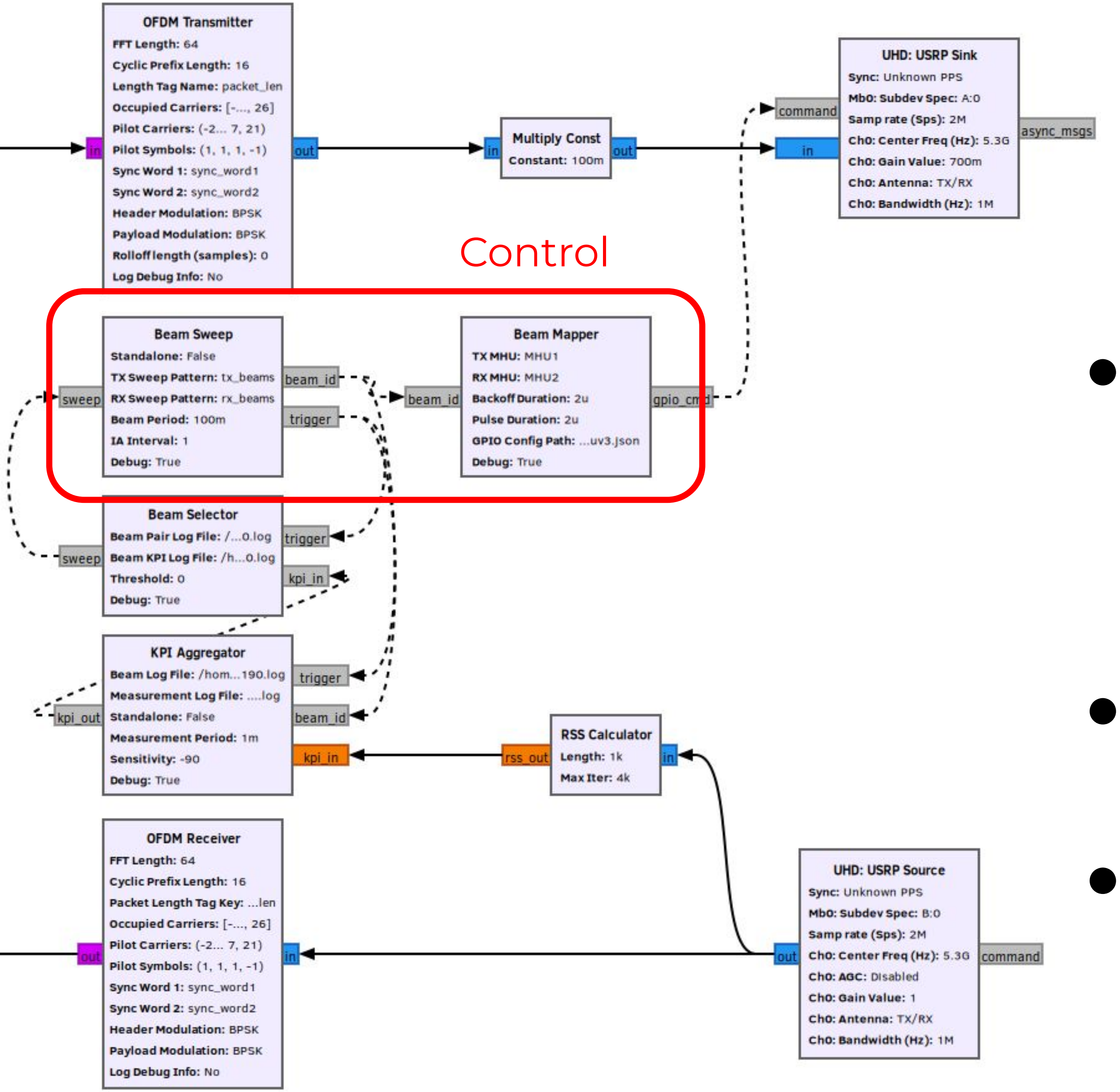
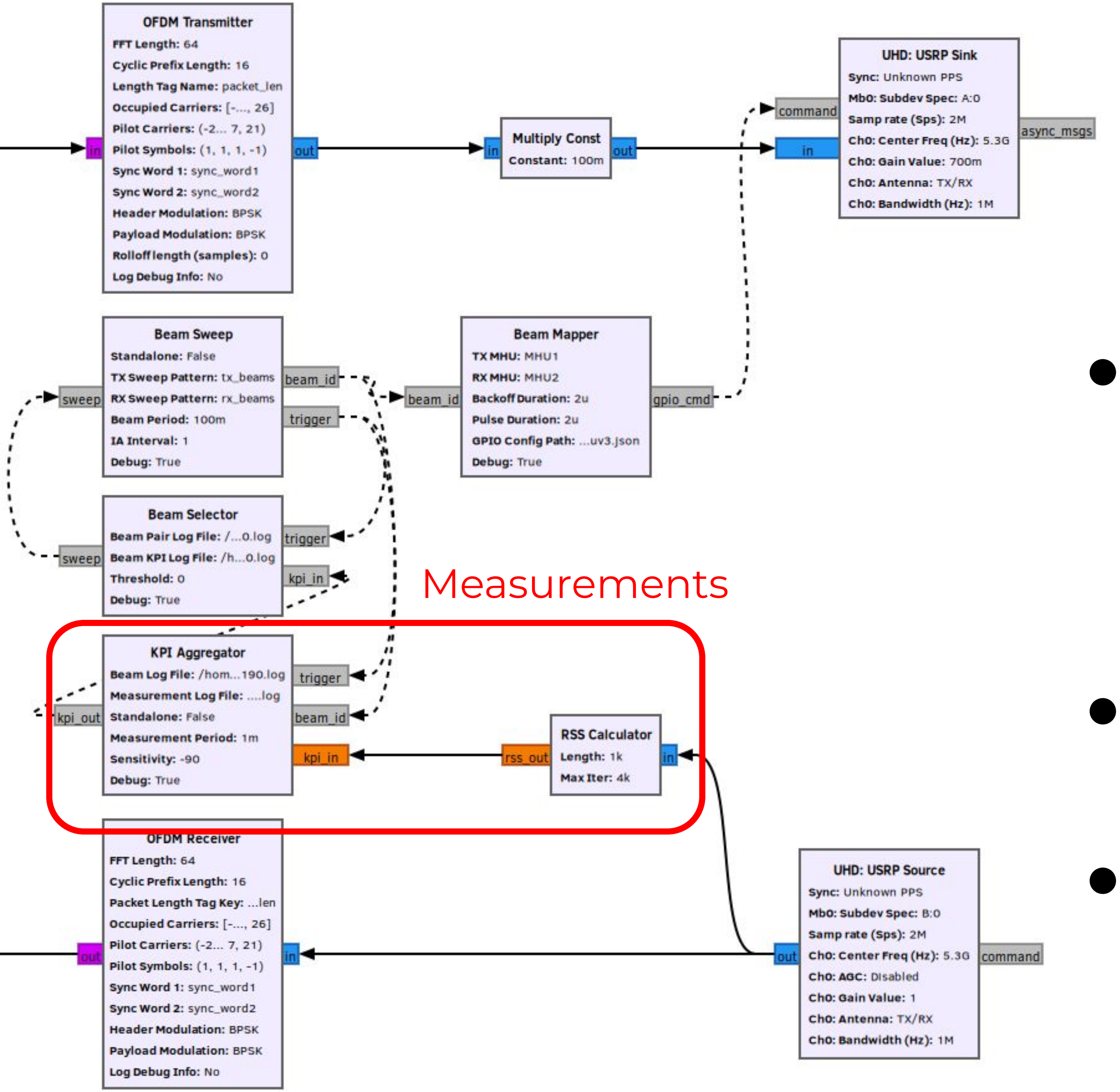
Realization in GNU Radio



- **Arbitrary** sweep sequences, beam durations, cadence of measurements
- Use blocks **standalone** or altogether
- **Asynch** messages to pass control information



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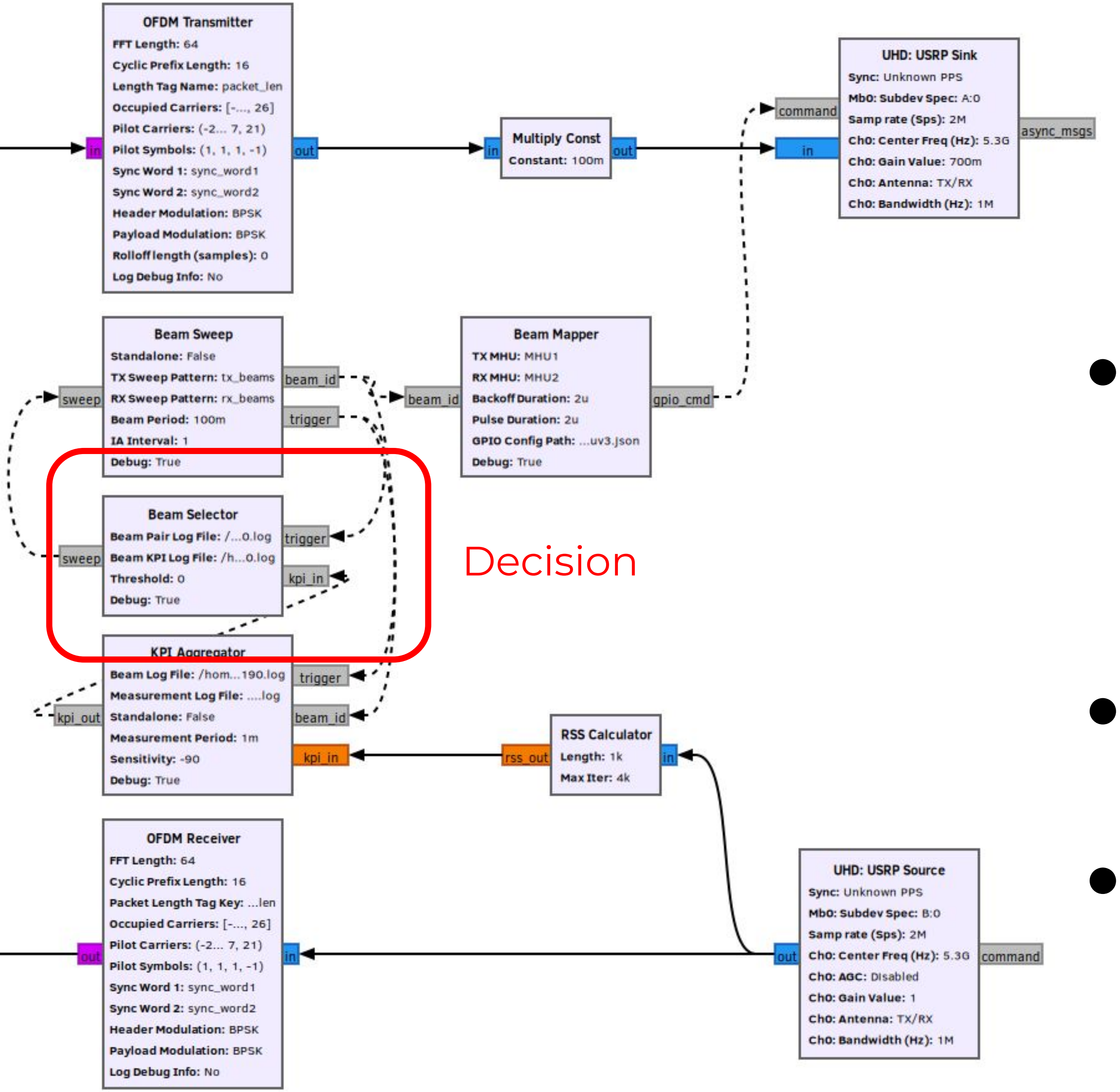
Realization in GNU Radio



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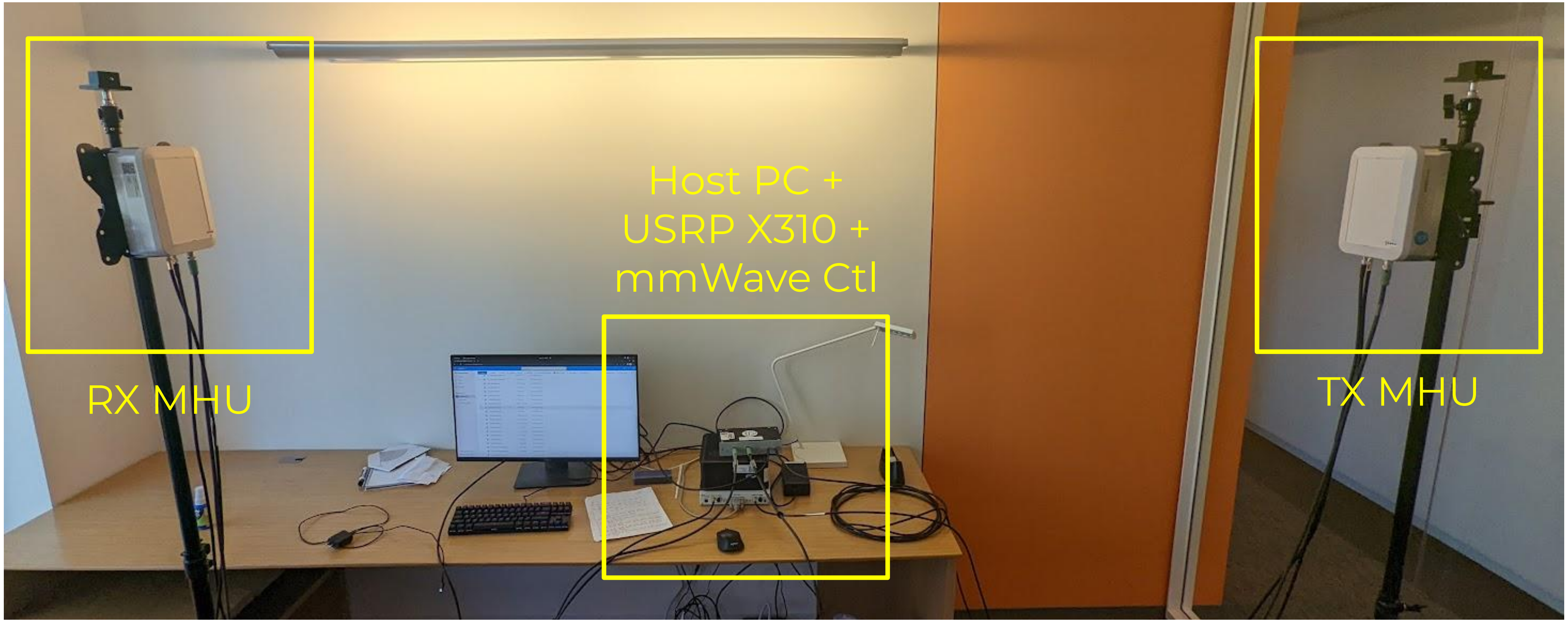
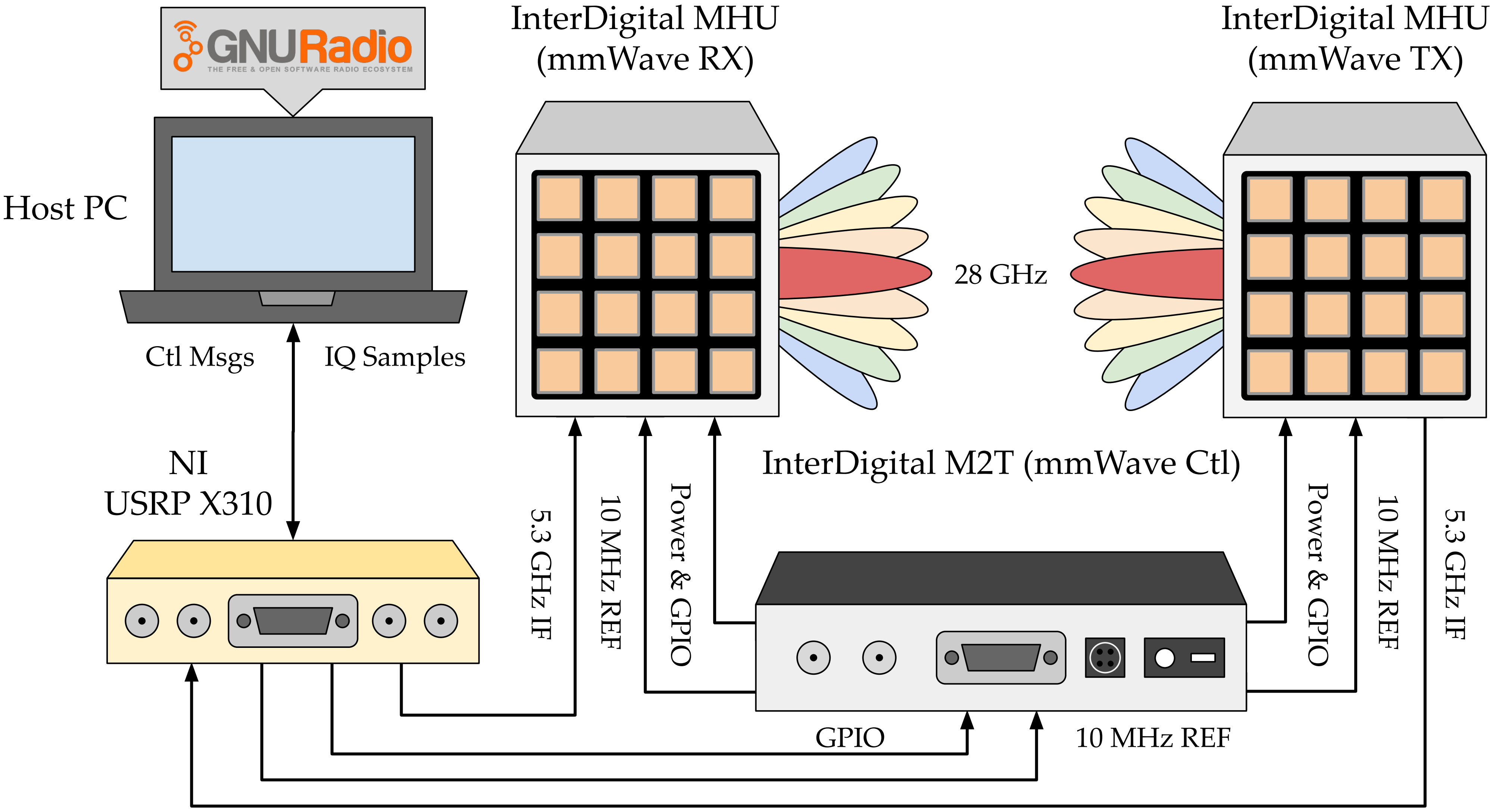
Development Setup

Hardware Components



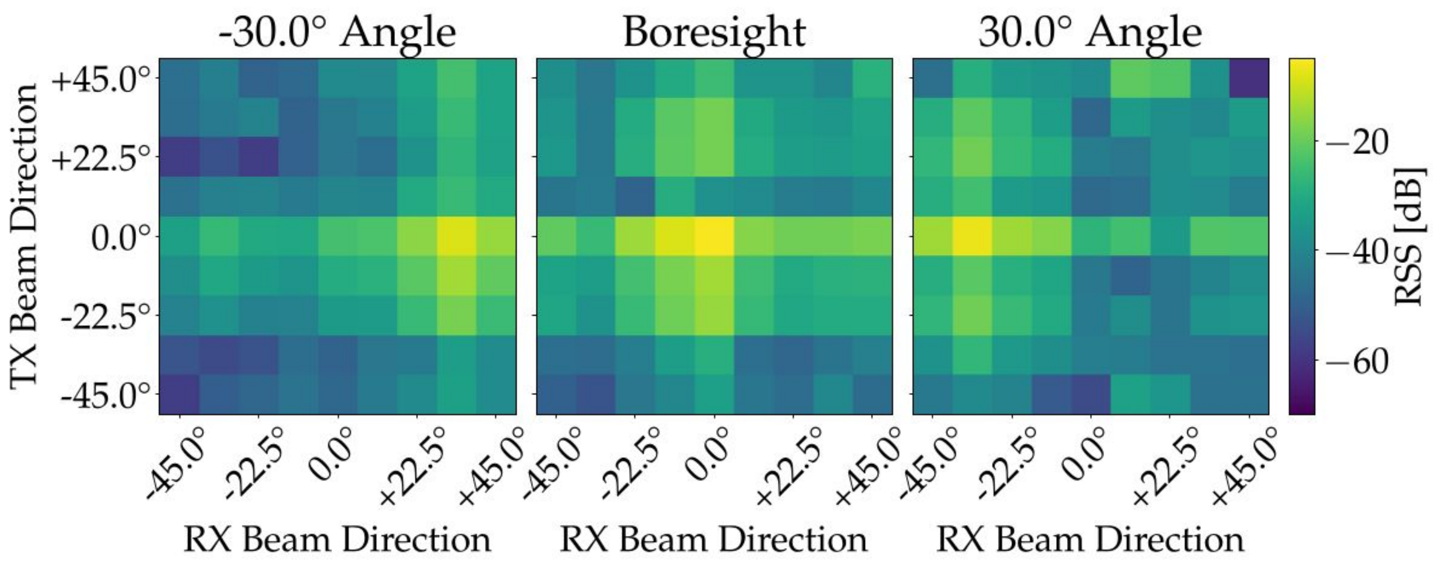
Development Setup

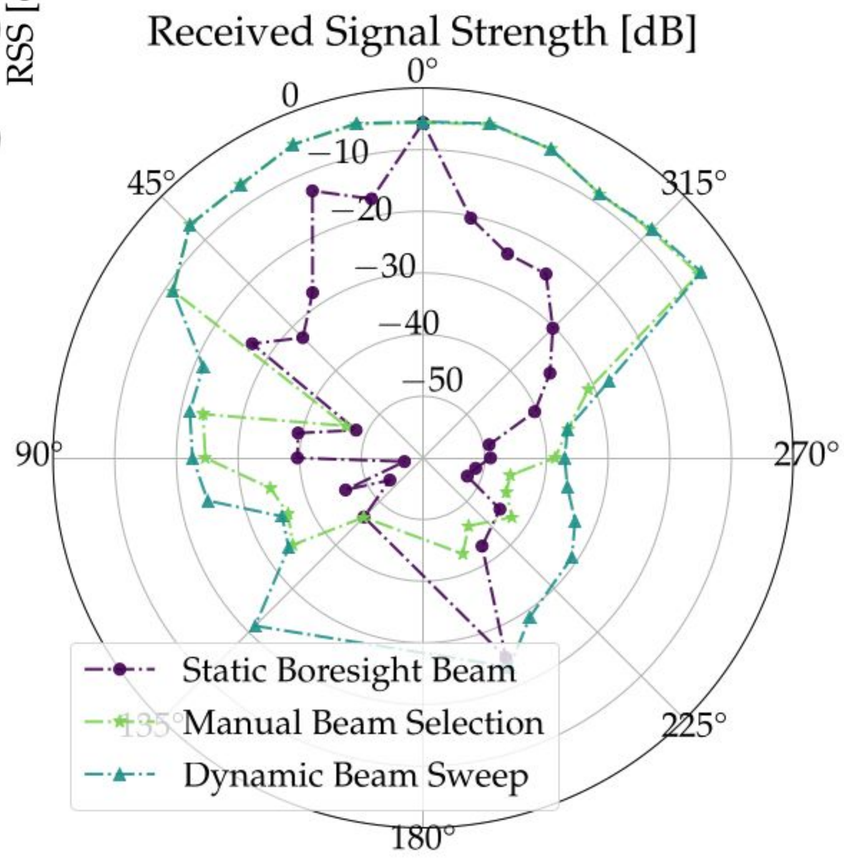
System Design



Experimental Results

Platform Validation





- Successfully controlled beams
- Observed different power levels according to orientation

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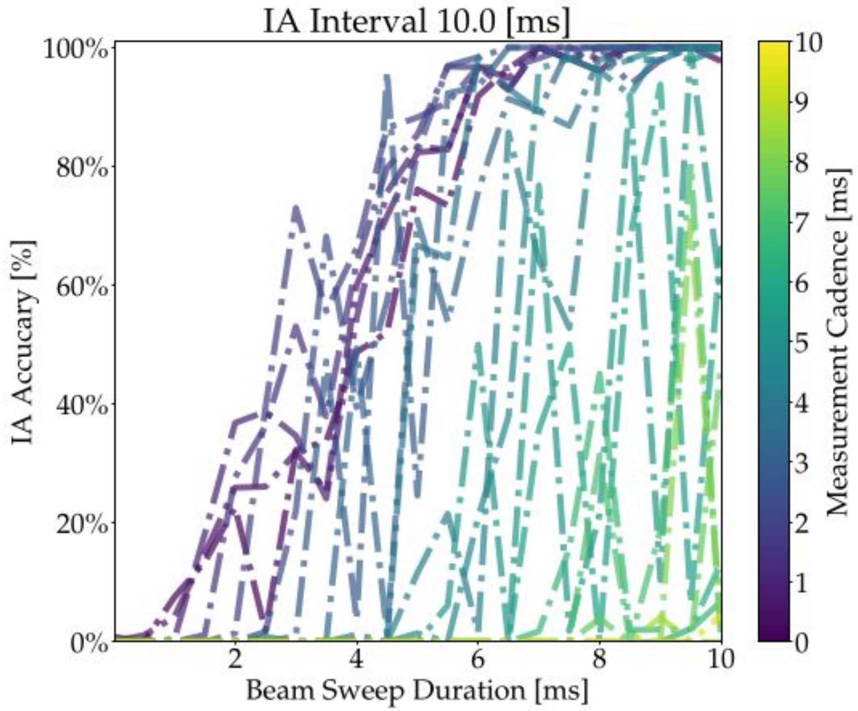
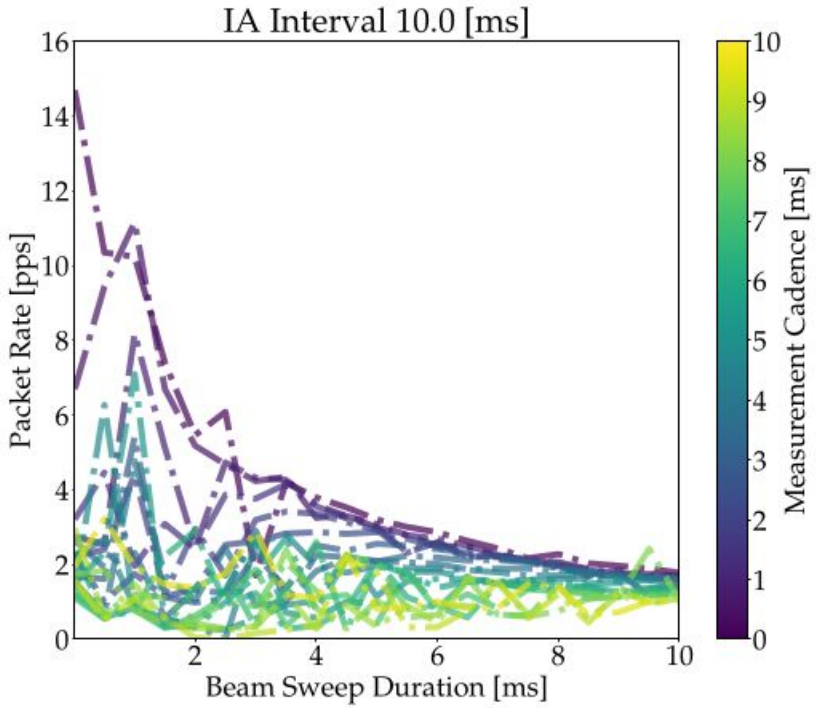
Experimental Results

Exploring the Flexibility of the Platform



(a) Accuracy of the IA procedure to select the correct beam pair, known a priori by design.



(b) Average packet rate obtained when transmitting data after running the IA procedures.

- Users can play with initial access parameters to obtain desired performance

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This Isn't Even My Final Form...

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- Still **work in progress**
- A couple things on our roadmap:
  - Replace async messages by something better
  - Mux between payload and known control frames

- Contact
  joaosantos@vt.edu
- Source code available on GitHub (but you'll need a front-end):
  https://github.com/CCI-NextG-Testbed/gr_stamina
- CCI xG Testbed (we are open to collaborations!)
  https://cyberinitiative.org/xg-testbed.html

Conclusions

Join us **November 7-8th**

NSF IUCRC Next G Center Planning Workshop

@ VT Research Center, Arlington VA

Registration: wisper@cyberinitiative.org