PSCR 2021

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AERIAL LTE NETWORK TESTING

Maxwell Maurice Electronics Engineer

HIGHLY MOBILE DEPLOYED NETWORKS

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* Please note, unless mentioned in reference to a NIST Publication, all information and data presented is preliminary/in-progress and subject to change.

SESSION OVERVIEW

This on-demand session will outline PSCR's work on aerial LTE deployments.

We will describe the project, the motivation for collecting these measurements, the test method, some results, best practices and recommendations.

SPEAKER

MAXWELL MAURICE

Electronics Engineer

B.S. Engineering Physics, CU Boulder 2018
M.E. Electrical Engineering Student, CU Boulder

HIGHLY MOBILE DEPLOYED NETWORKS

HIGHLY MOBILE DEPLOYED NETWORKS

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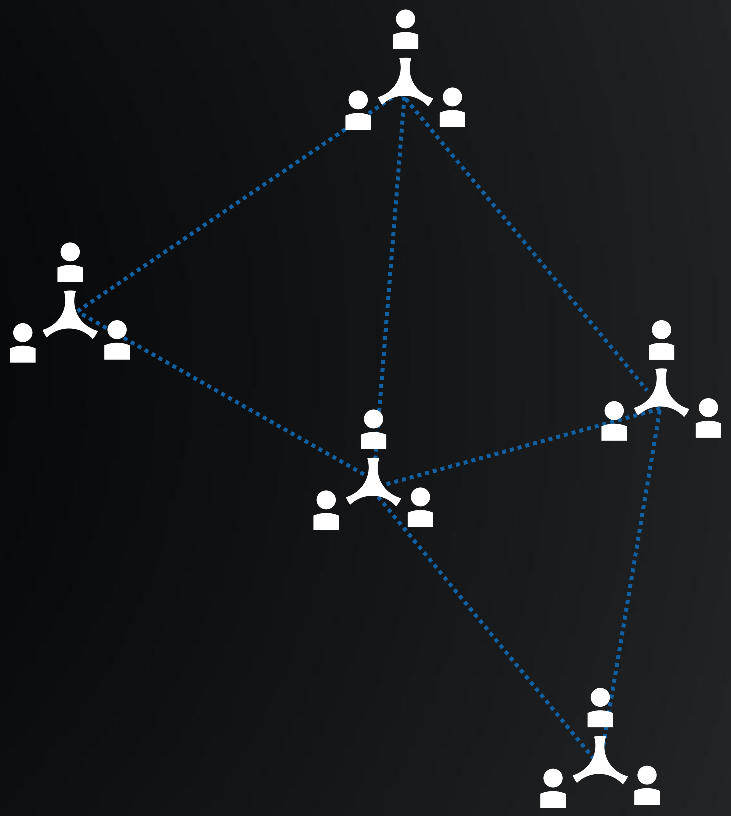
HIGHLY MOBILE DEPLOYED NETWORKS

PROJECT MOTIVATION

The availability of deployable systems is a critical need for remote areas where complete coverage is not feasible and areas where installed resources are compromised. Broadband services and communications need to be maintained for any first responder scenario.

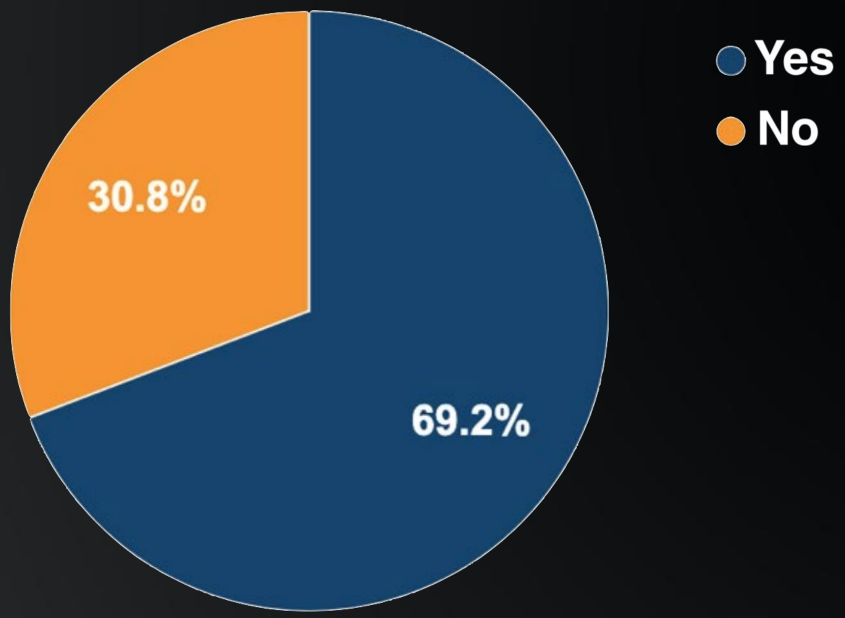


PROJECT GOAL

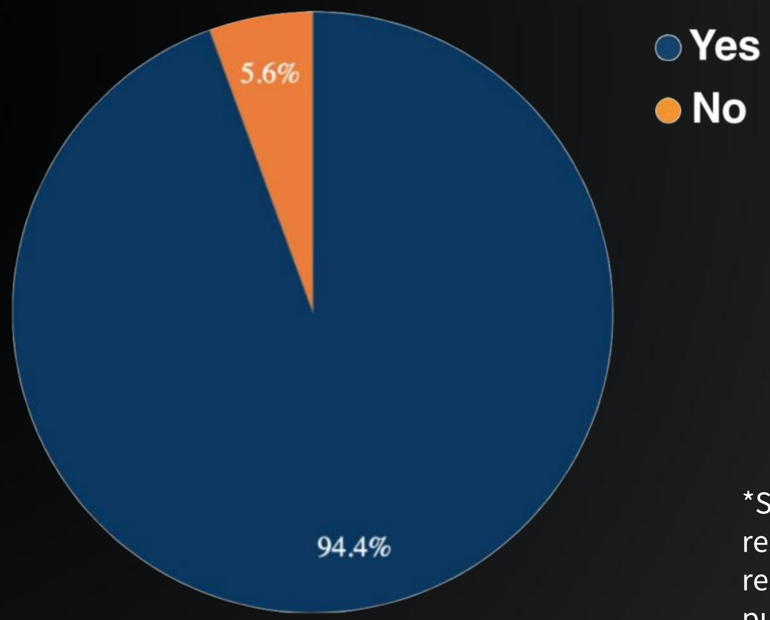
Perform research on the operation and intercommunication between components of single and multiple deployable systems to share resources, information, and services among users.

PROJECT MOTIVATION

Have you been involved in any missions during which cellular broadband communications were not available?



Where cellular broadband communications were not available, was there a need for, or would you have wanted, wireless communications?

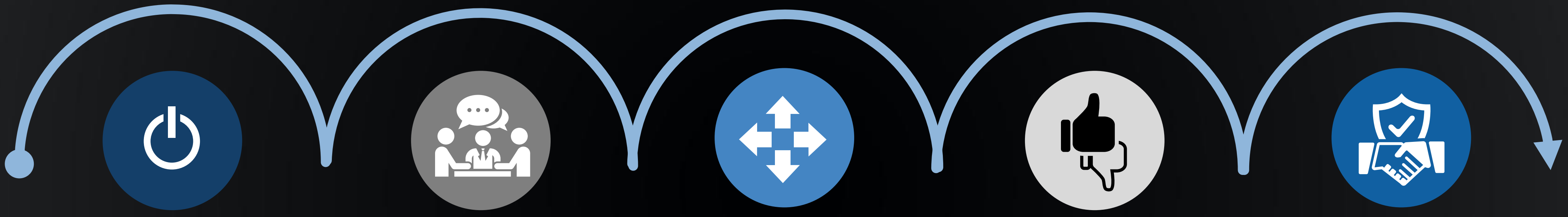


*Survey included 183 responses from first responders and public safety drone experts.

https://www.nist.gov/publications/survey-drone-usage-public-safety-agencies

HIGHLY MOBILE DEPLOYED NETWORKS

2017 2018 2019 2020 2021



YEAR 2017
Latency testing
Power consumption
Interference testing
Deployment testing
Mobile ad hoc network research

YEAR 2018
Round table meeting
Summit meeting
ICN* for deployables
Overall architecture
Airborne simulation

YEAR 2019
Ground vehicle-based testing
Tech to Protect Challenge
UAS field testing
Service load testing
Unlicensed spectrum
Access technologies

YEAR 2020
Winter Institute
DEDUCE
Service federation
Coverage prediction
Service prediction

YEAR 2021
Aerial testing
5G testing

*Information-Centric Networking (ICN)

TESTING BACKGROUND

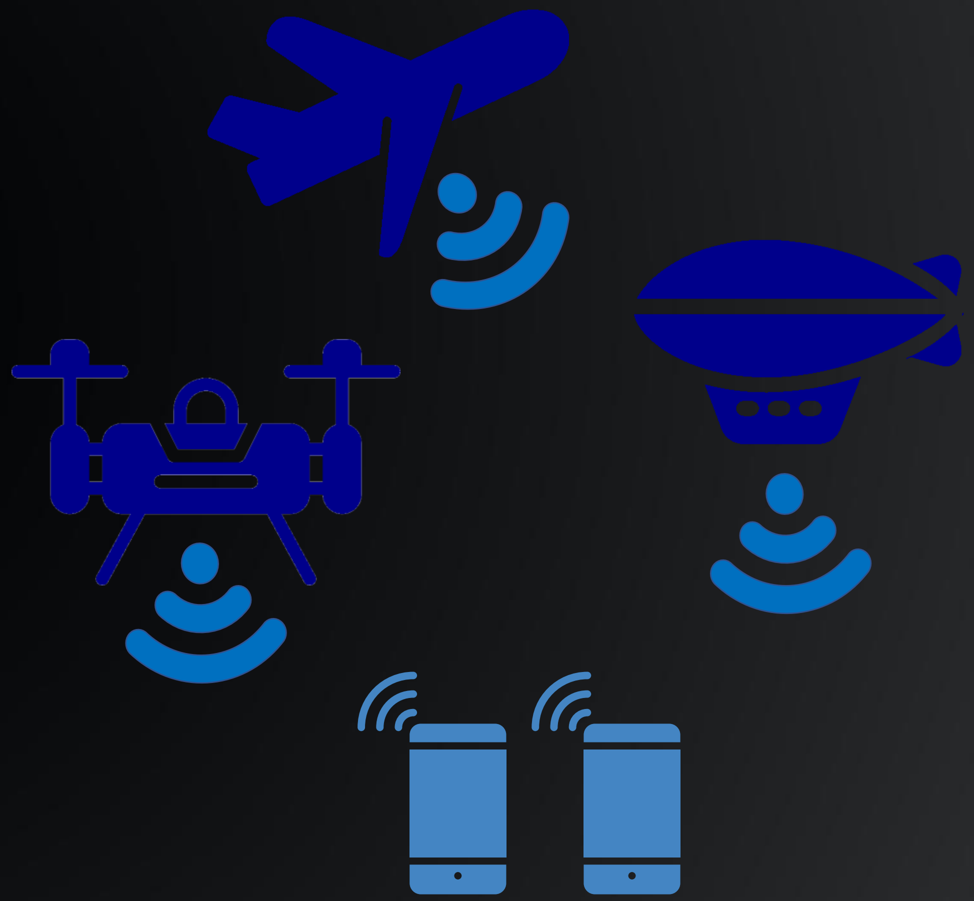
TESTING BACKGROUND

WHAT ARE AERIAL COMMS?

- Systems in the air that broadcast a wireless link to users on the ground

- For the communication system, it could be:
  - Cellular (3G, 4G, 5G, etc.)
  - 802.11 variant (Wi-Fi)
  - Proprietary mesh radio

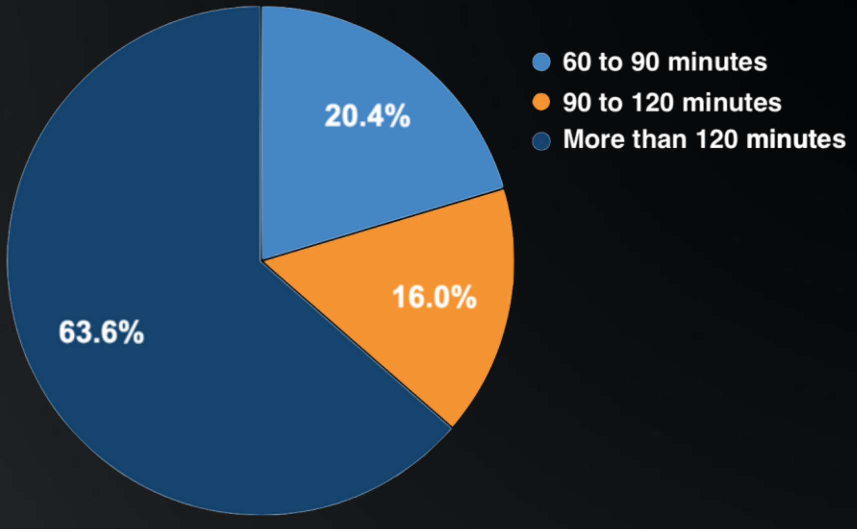
- The delivery platform could be:
  - Multi-rotor drones
  - Fixed-wing drones
  - Vertical takeoff and landing (VTOL) hybrid systems
  - Aerostats



TESTING BACKGROUND

DRONE BOUNDARIES

- Must be under 25 kg (55 lb) for FAA Part 107 regulations
- Must be able to lift the communication system payload (2 kg to 4.5 kg, or 4 lb to 10 lb)
- Needs to be relatively affordable (~$30,000)
- Multi-rotor preferred
- Be mobile and untethered
- Endurance over 120 minutes



TESTING BACKGROUND

ISSUE

- There are a limited number of solutions that fit the requirements by public safety.

SOLUTION

- Live with the low endurance
- Consider alternative operations
- Strive to push industry in this direction
- Choose other drone types

UAS CHALLENGE 2021

ELEVATE • ENDURE • SUPPORT

https://www.firstresponderuaschallenge.org/

TESTING BACKGROUND

FIXED-WING sUAS

- Small Unmanned Aircraft System (sUAS)
- More efficient
- Highly mobile (if that is desired)
- Can loiter in a circular pattern
- More difficult, but not impossible to pilot

Two fundamental differences for a fixed-wing sUAS

1. Fixed-wing drones must be in lateral motion for flight.

2. The use of fixed-wing drones will introduce rapidly varying distances to receivers on the ground.

TESTING BACKGROUND

FIXED-WING RESEARCH QUESTIONS

1. Motion may have unintended effects on the link between an eNodeB and User Equipment (UE). Does eNodeB motion cause link degradation to a UE on the ground?

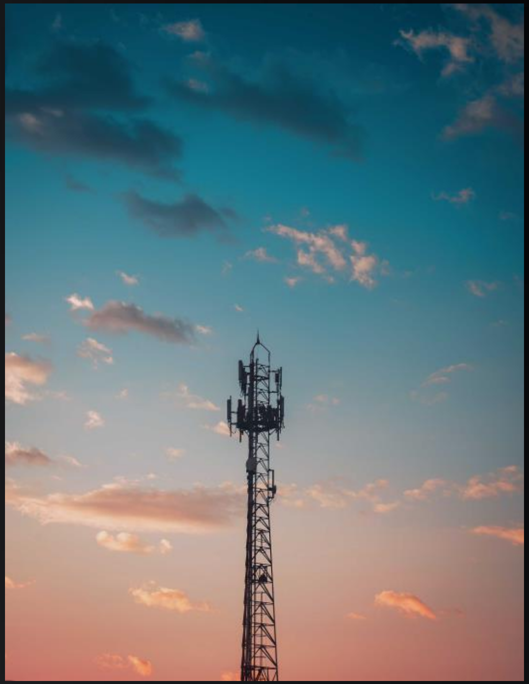
2. Rapidly varying distances between an eNodeB and a UE will cause fluctuating link qualities. What does this link look like between an eNodeB and a UE on the ground?

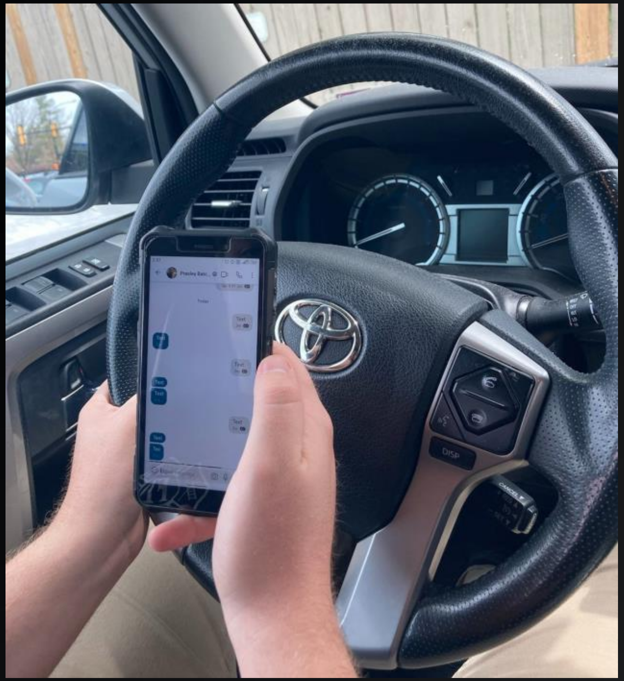
3. It can take several seconds for a UE to attach to a network when an eNodeB reference signal is first picked up. The delay in having a phone attach to the LTE network would shrink the expected coverage area provided by the system. What would the new effective coverage area be?

TESTING BACKGROUND

PREDICTIONS

1. Motion may have unintended effects on the link between an eNodeB and User Equipment (UE). Does eNodeB motion cause link degradation to a UE on the ground? No, motion should not affect the link.

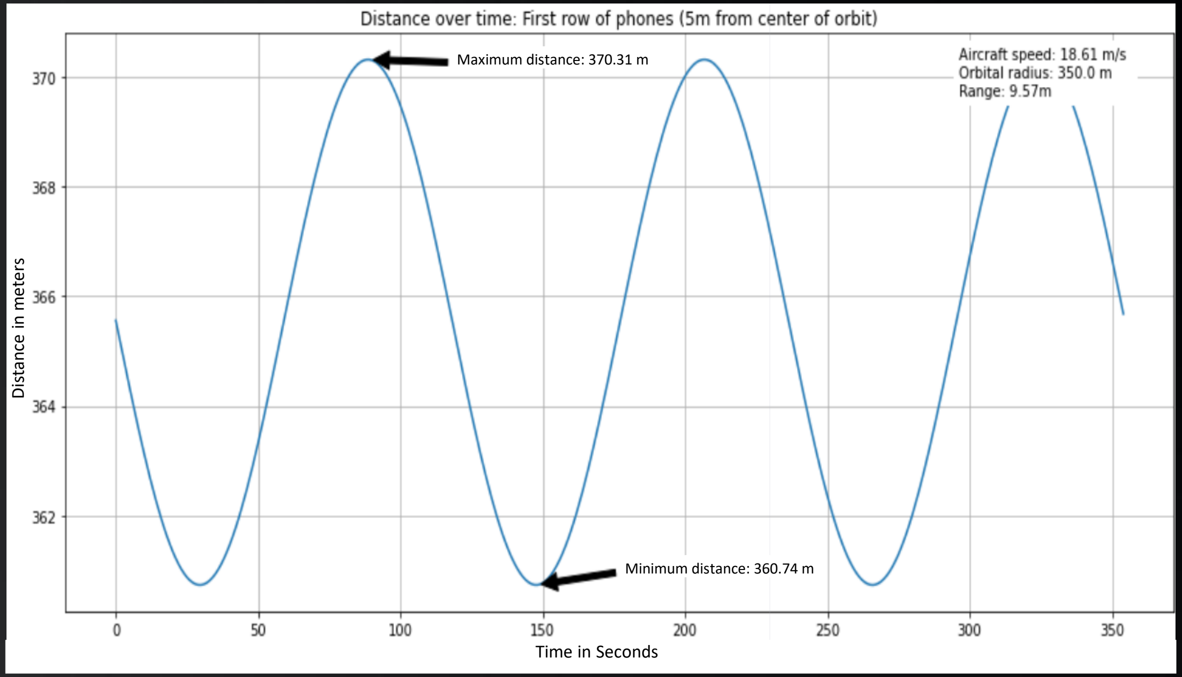


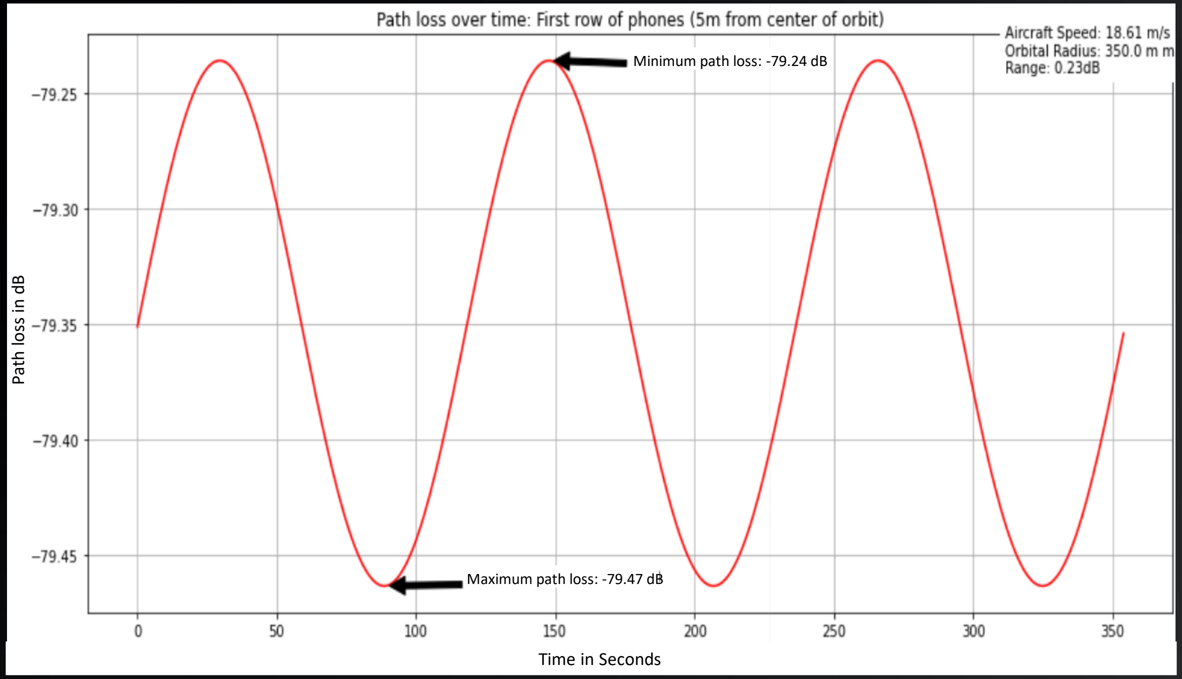


TESTING BACKGROUND

PREDICTIONS

2. Rapidly varying distances between an eNodeB and a UE will cause fluctuating link qualities. What does this link look like between an eNodeB and a UE on the ground? UE Path loss and distance should look like this if the device is close to the center of orbit.

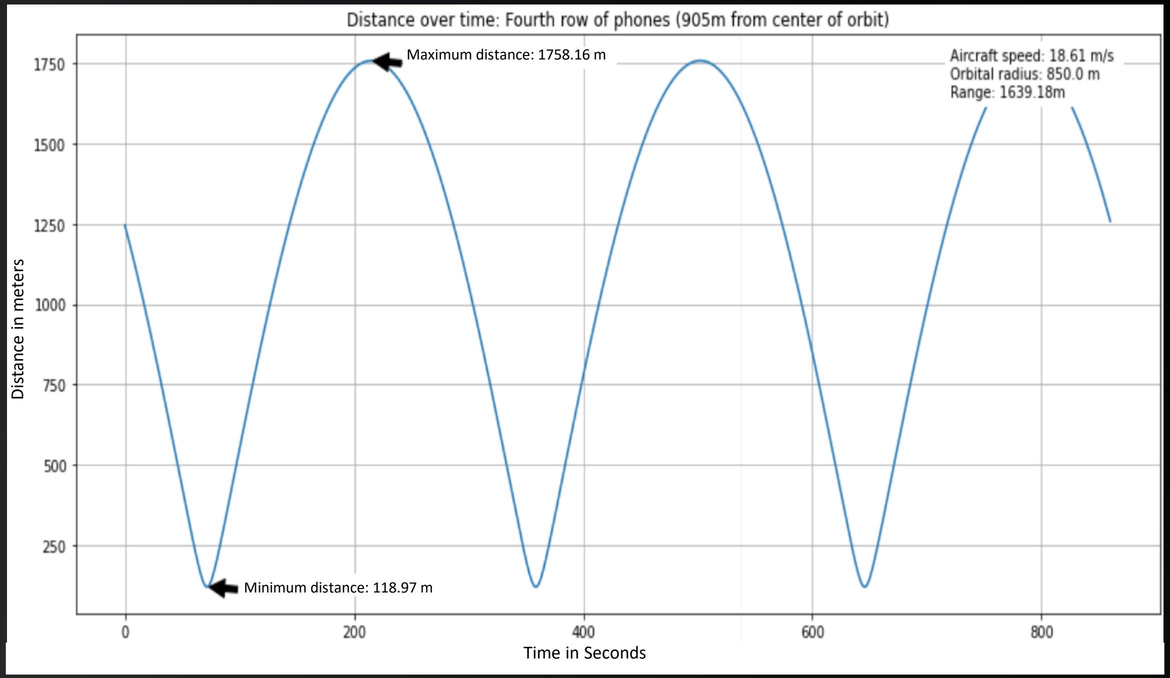


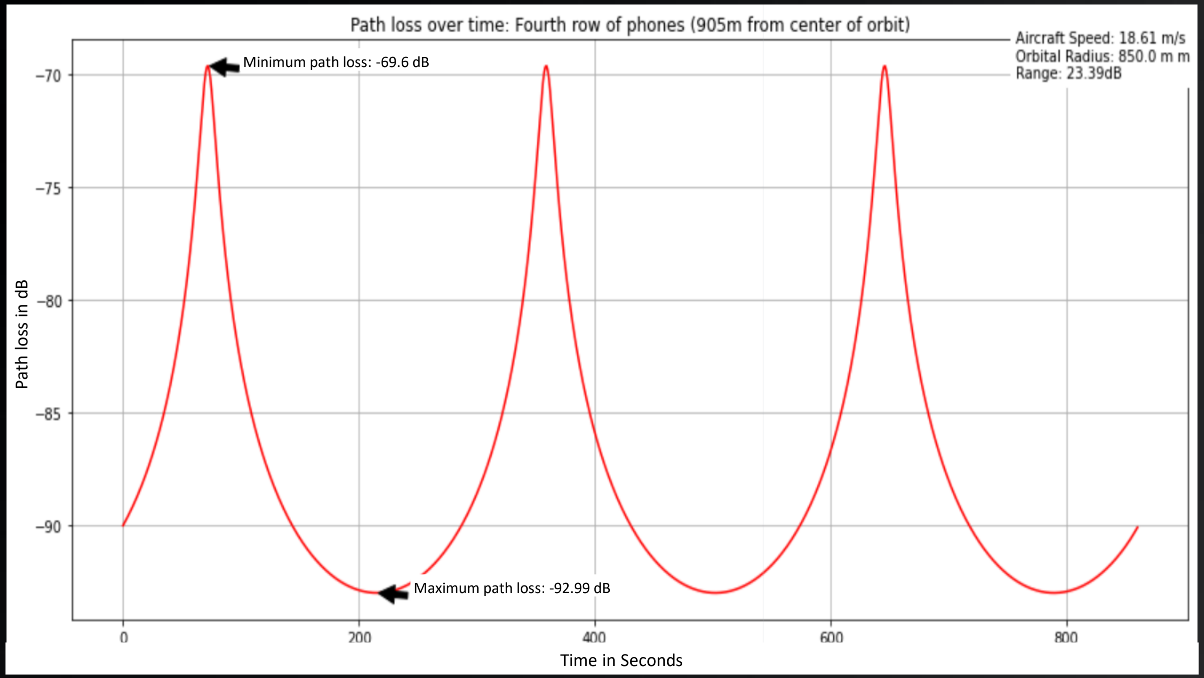


TESTING BACKGROUND

PREDICTIONS

2. Rapidly varying distances between an eNodeB and a UE will cause fluctuating link qualities. What does this link look like between an eNodeB and a UE on the ground? UE Path loss and distance should look like this if the device is outside the orbital path.





TESTING BACKGROUND

PREDICTIONS

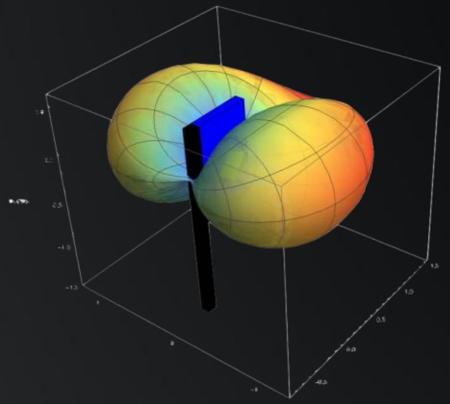
3. It can take several seconds for a UE to attach to a network when an eNodeB reference signal is first picked up. The delay in having a phone attach to the LTE network would shrink the expected coverage area provided by the system. What would the new effective coverage area be? It is a smaller coverage area, but by how much?

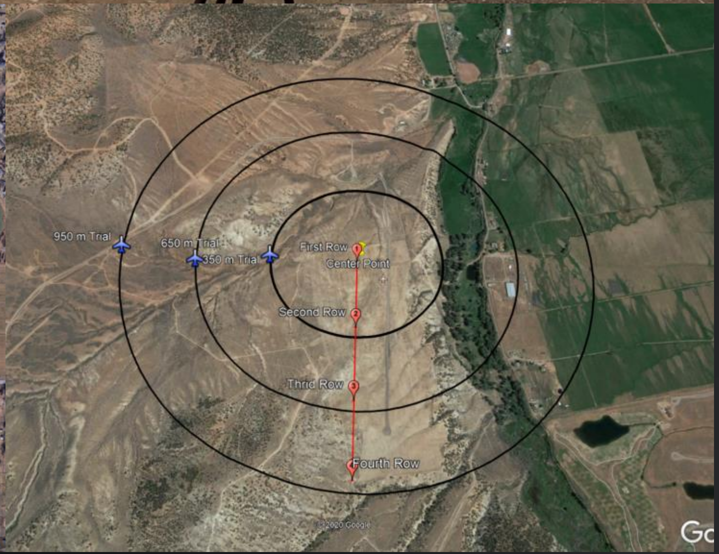
TESTING

TEST SETUP

TESTS

- 4 tests total
  - Close-range baseline test
  - Full-range baseline test
  - 350-meter test (orbital radius)
  - 650-meter test (orbital radius)
- 2 different test locations
- 12 smart phones from 3 vendors with tripods
- LTE monitoring smartphone app
- 1 Watt band 14 LTE transmitter
- Low gain directional antenna

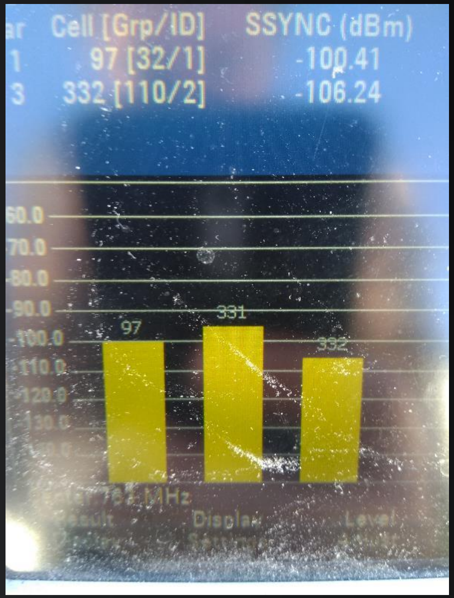




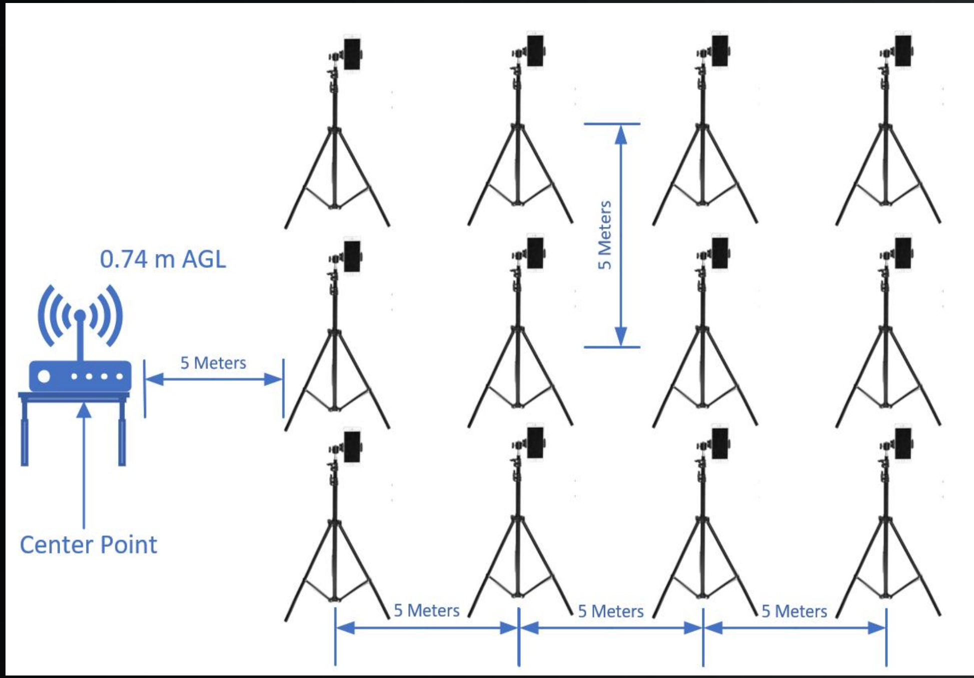
TEST SETUP

TESTS

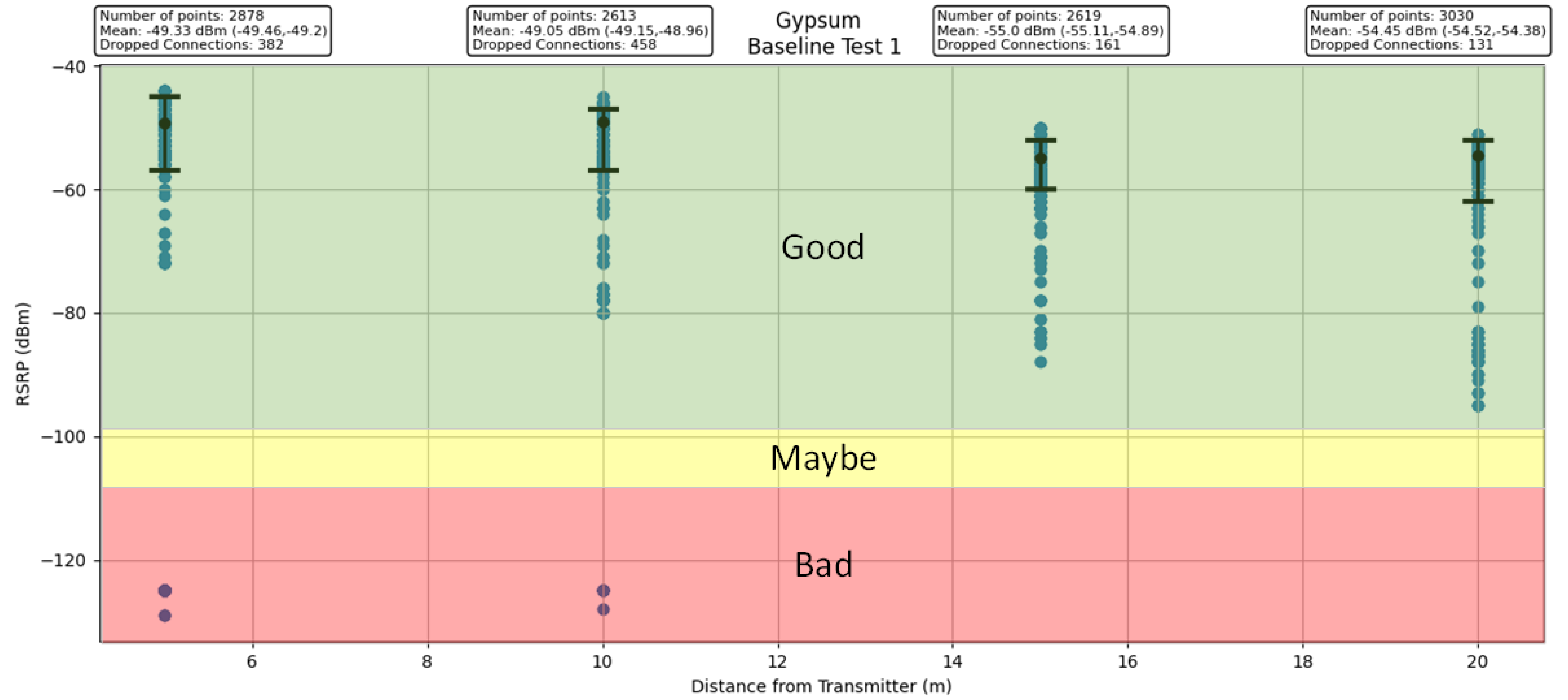
AT&T cell sites present at both locations. This raises the noise floor considerably for tests. In some cases, the sites were measured to be less than -110 dBm RSRP, but in other cases it was as high as -95 dBm.



CLOSE-RANGE BASELINE TEST



CLOSE-RANGE BASELINE TEST



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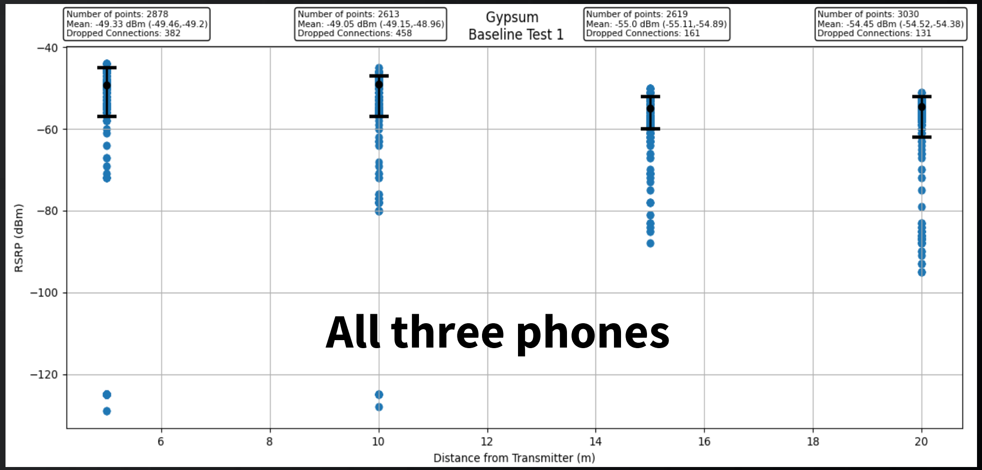
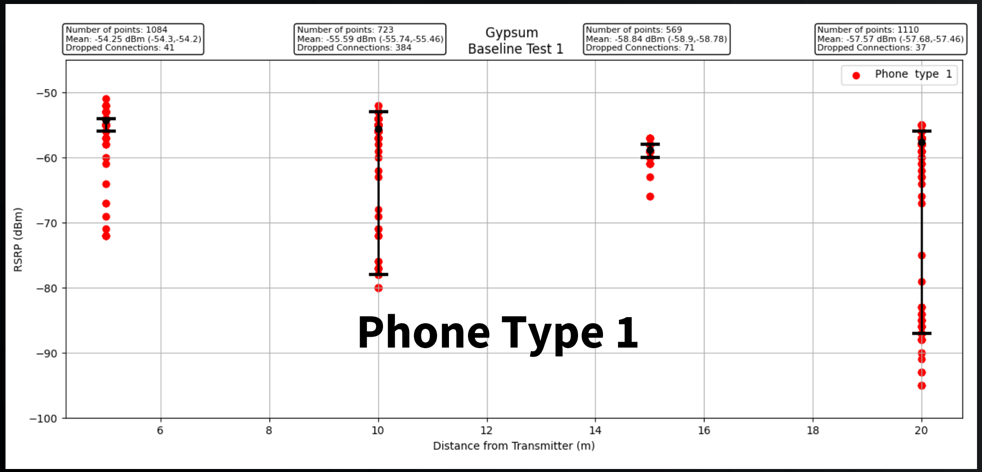
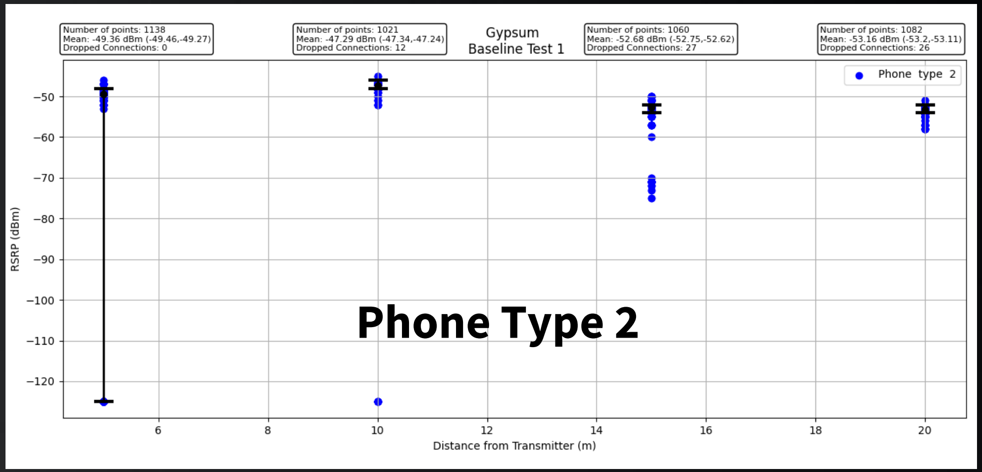
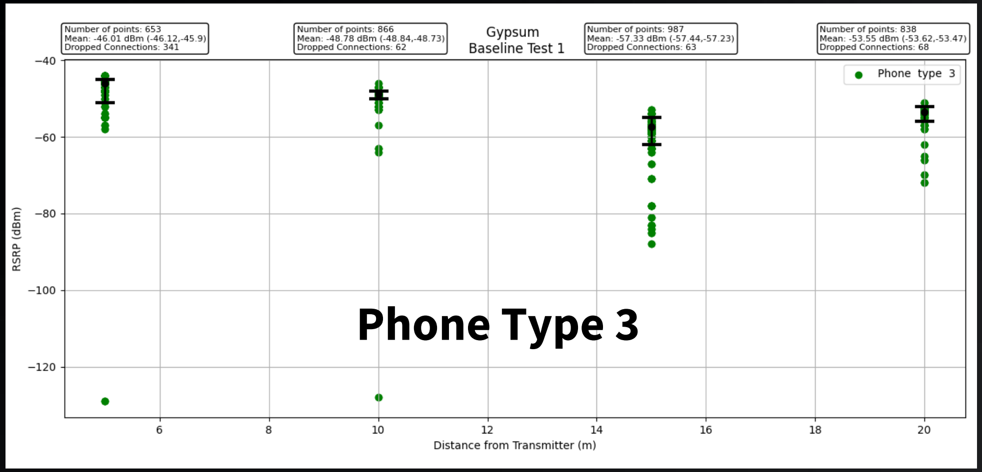
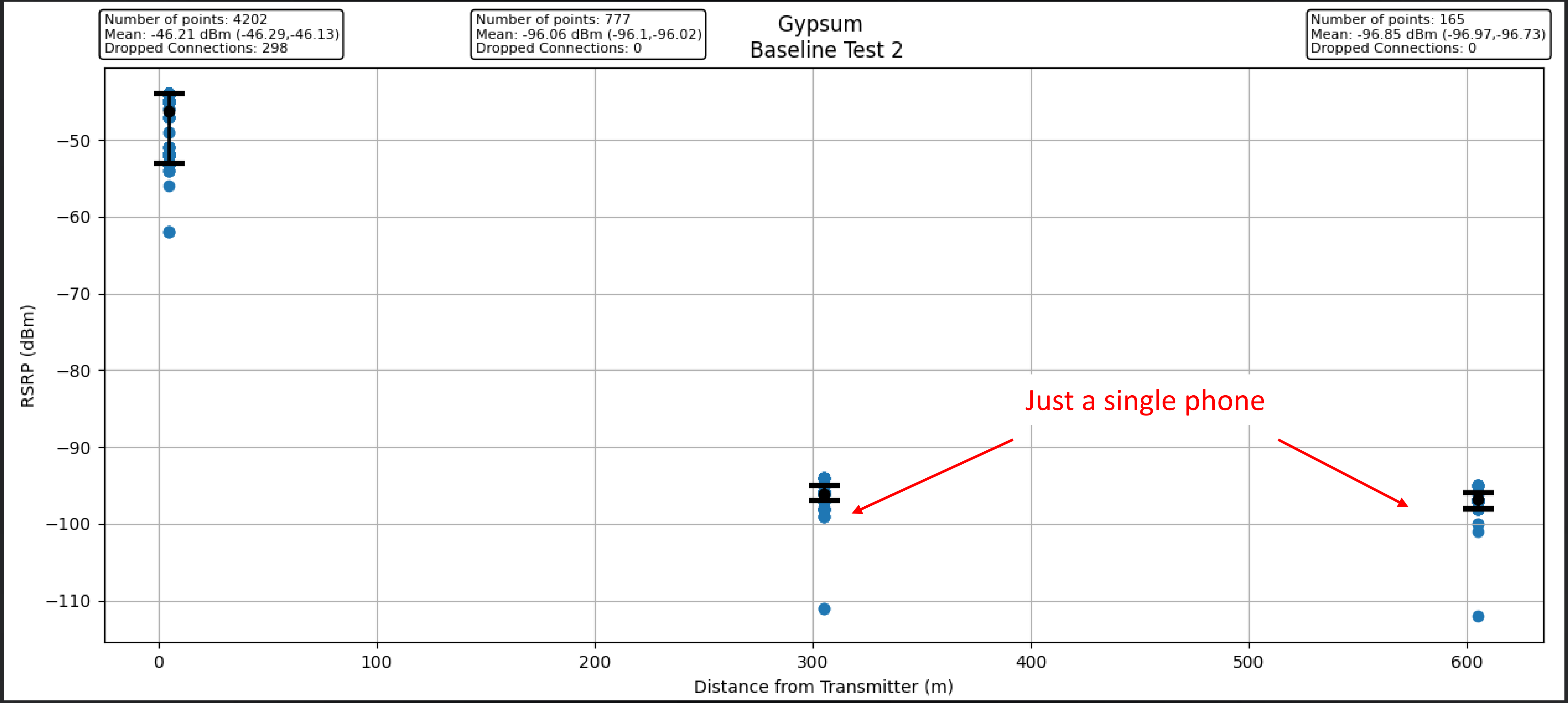




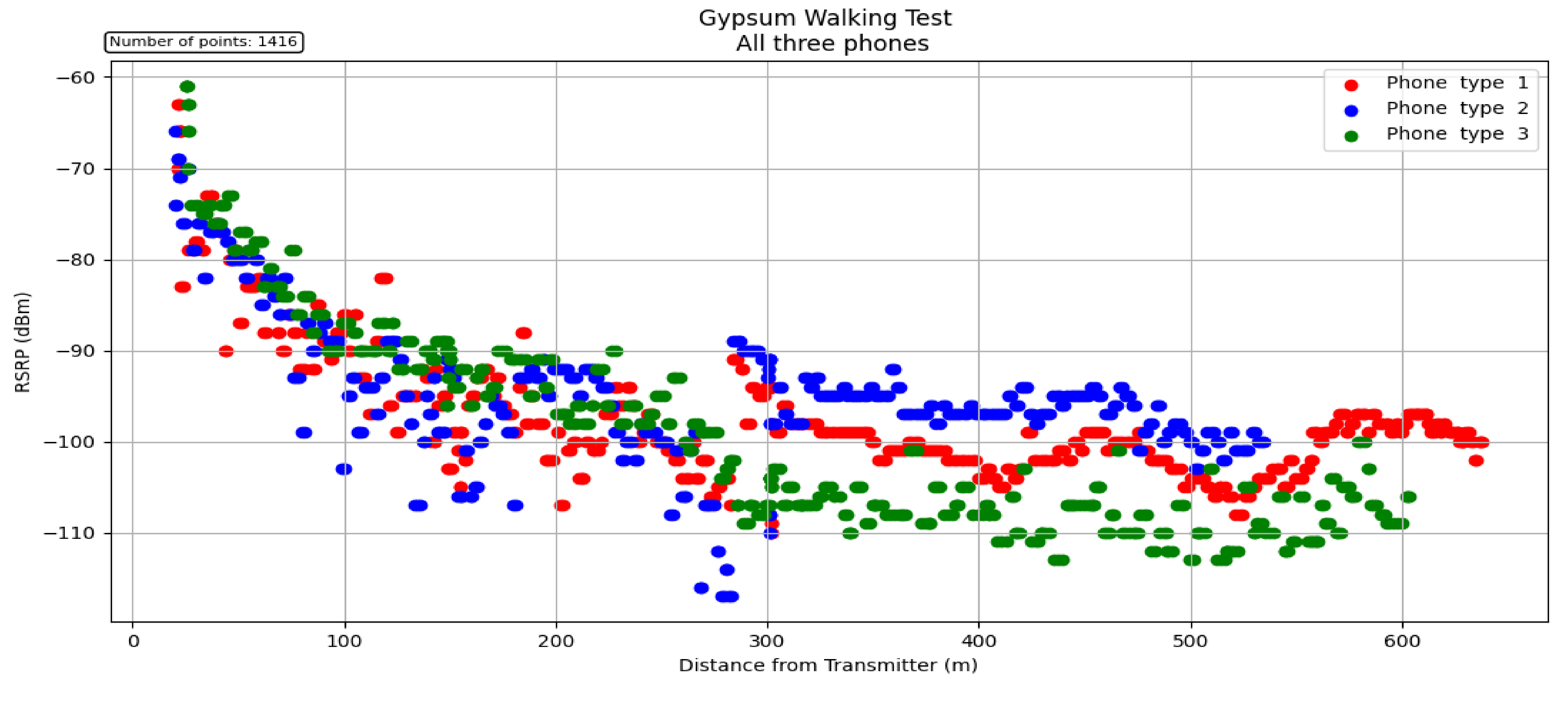




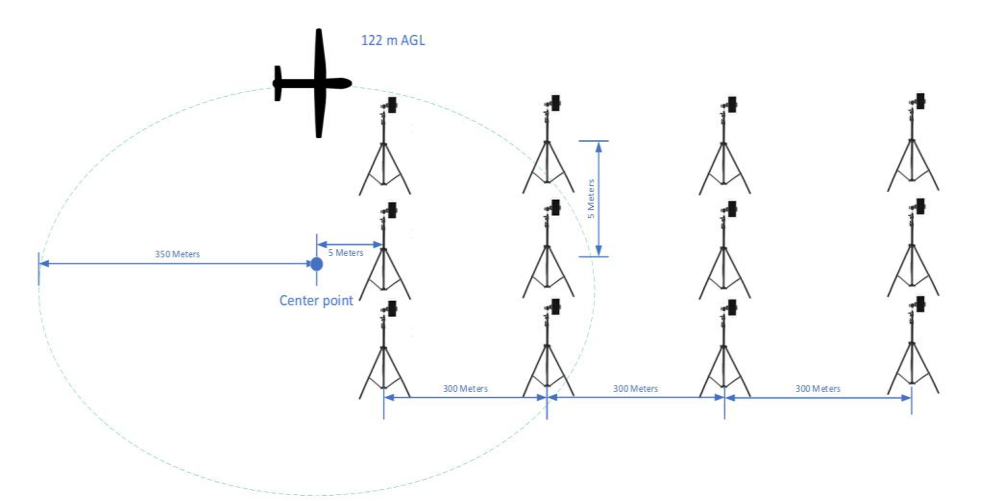
FULL-RANGE BASELINE TEST



WALKING TEST



AERIAL TESTS

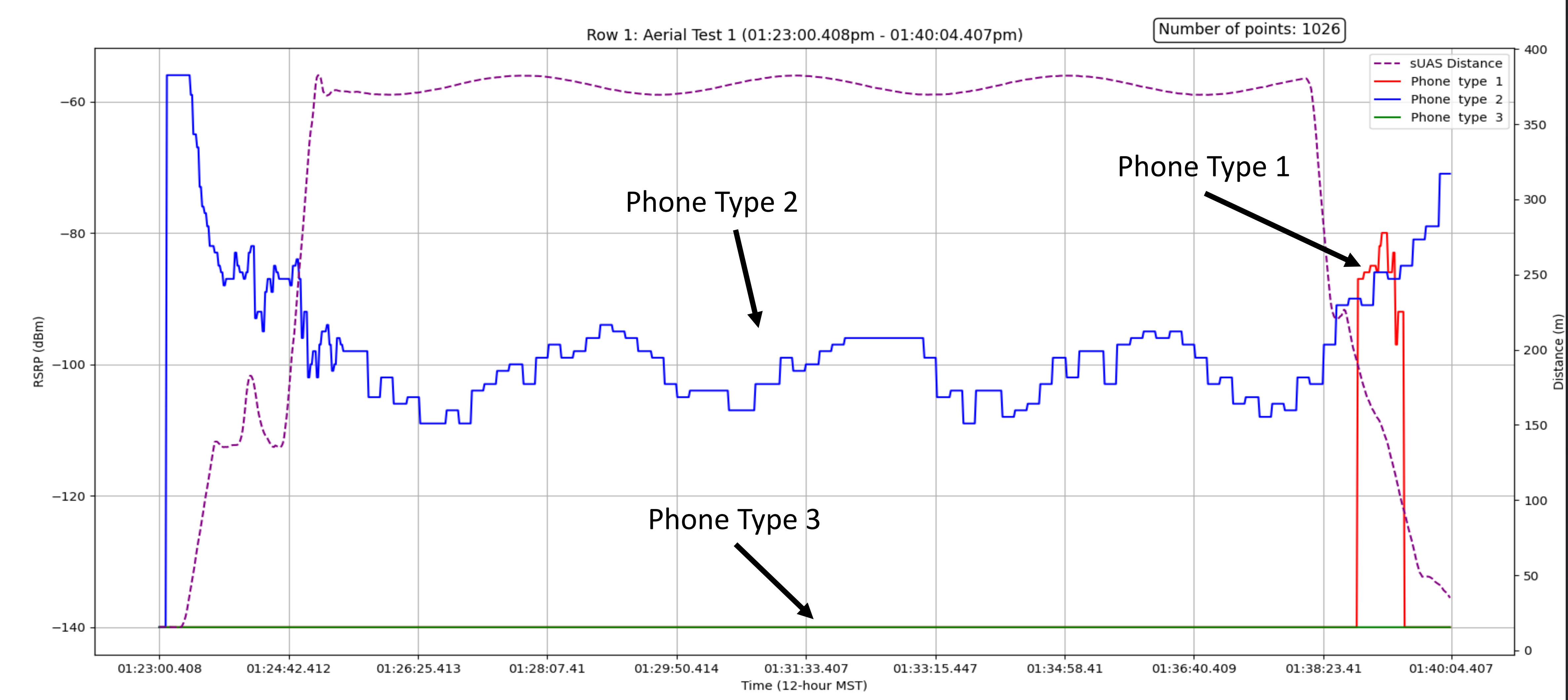


AERIAL TESTS

AERIAL TESTS

If you cannot view the video on this slide, please view the recorded presentation at pscr.gov

350-METER TEST



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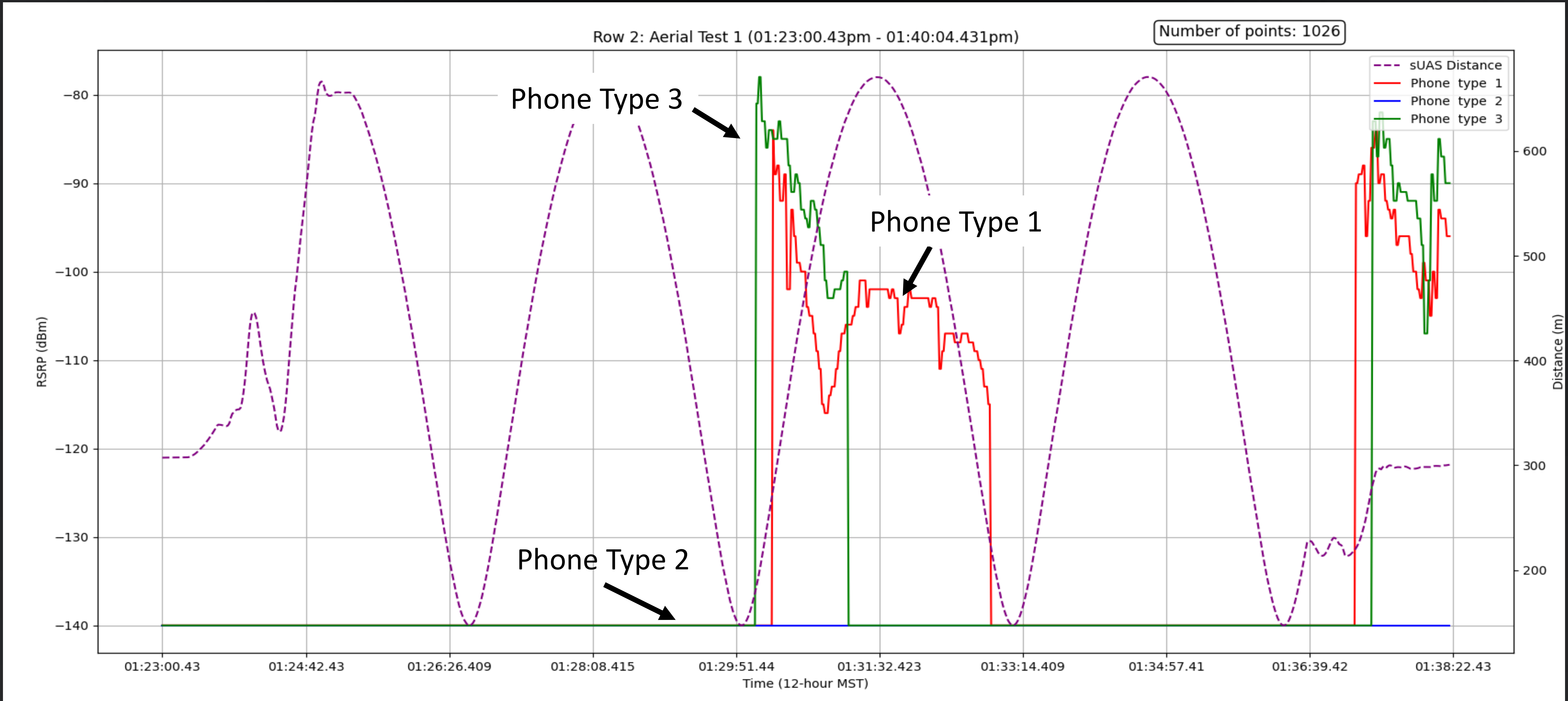
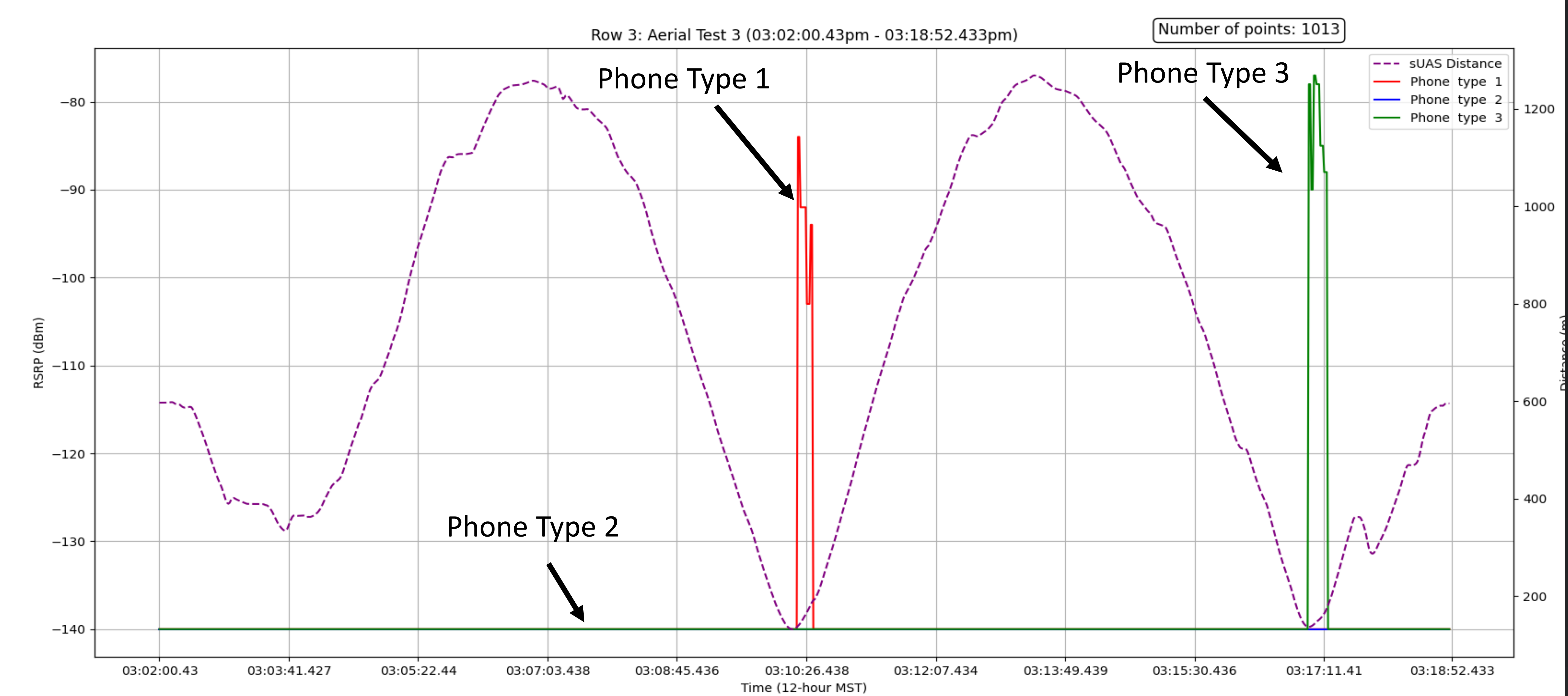


HIGHLY MOBILE DEPLOYED NETWORKS

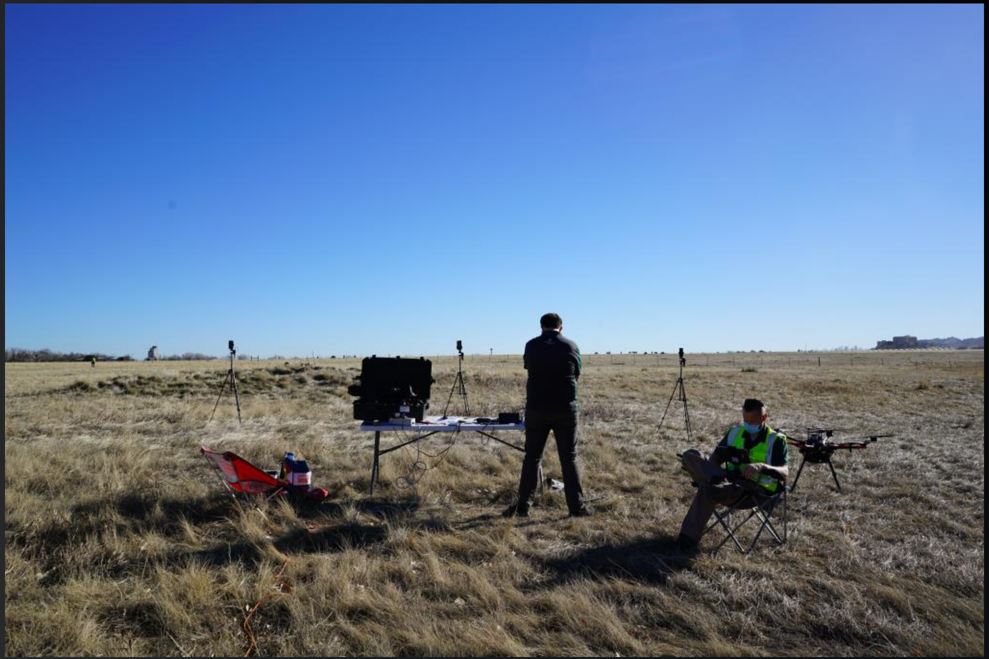
650-METER TEST



INITIAL CONCLUSIONS

RESULTS

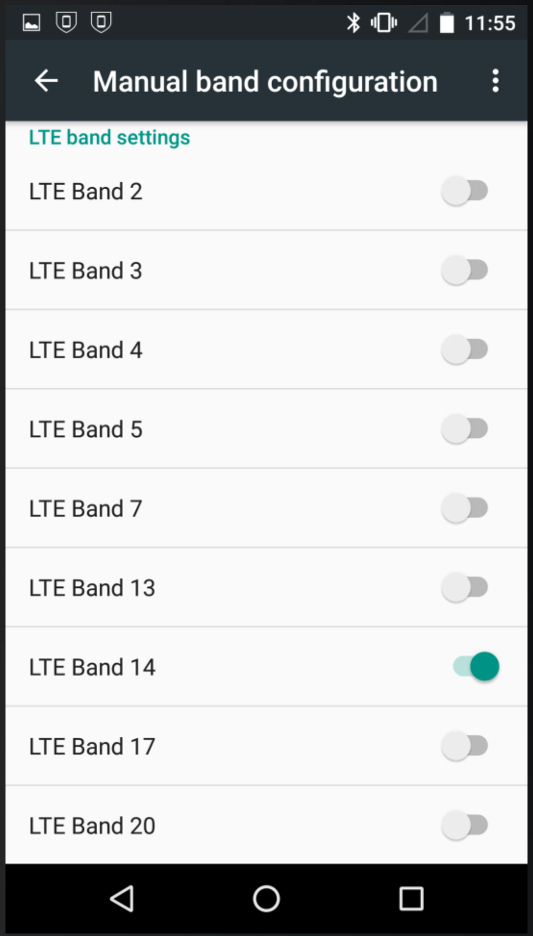
- Inconsistent connectivity
- Sporadic dropped measurements
- Small coverage footprint
- Fixed-wing platform challenges

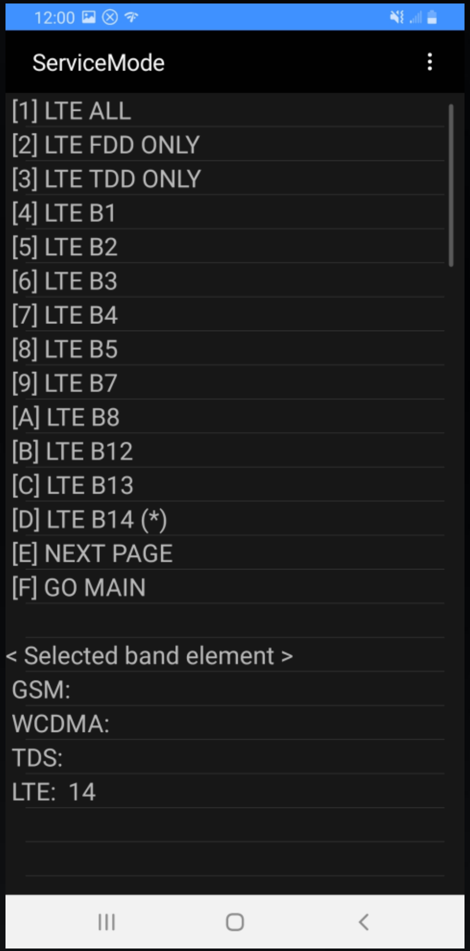


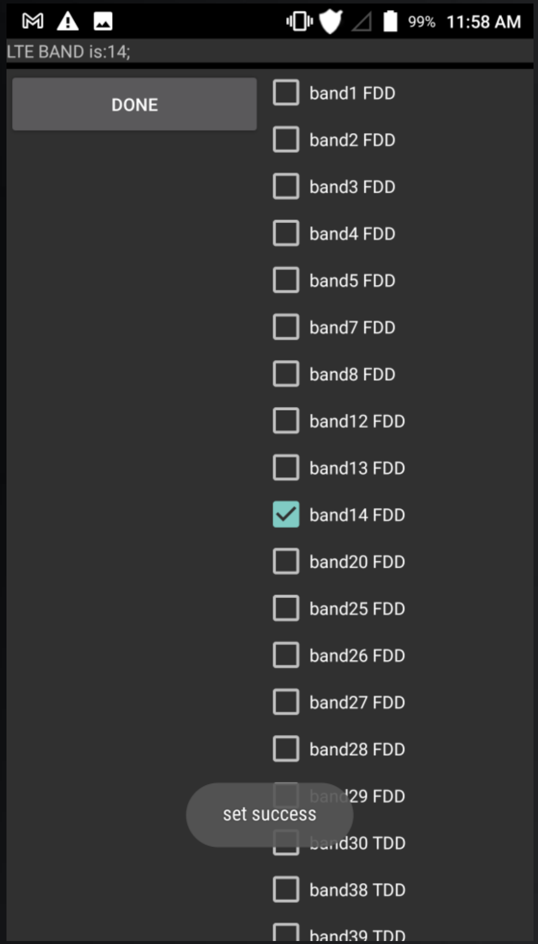
BAND LOCKING

BAND LOCKING

PHONES BAND LOCKED TO BAND 14







BAND LOCKING

NEW TESTS

- 2 tests total
  - 350-meter orbital radius test
  - 600-meter orbital radius test
- Fort Collins test site
- Only 1 smart phone variant
- New locations for smart phones
- Center phone is on table—not a tripod
- Band locked to transmitter

BAND LOCKING

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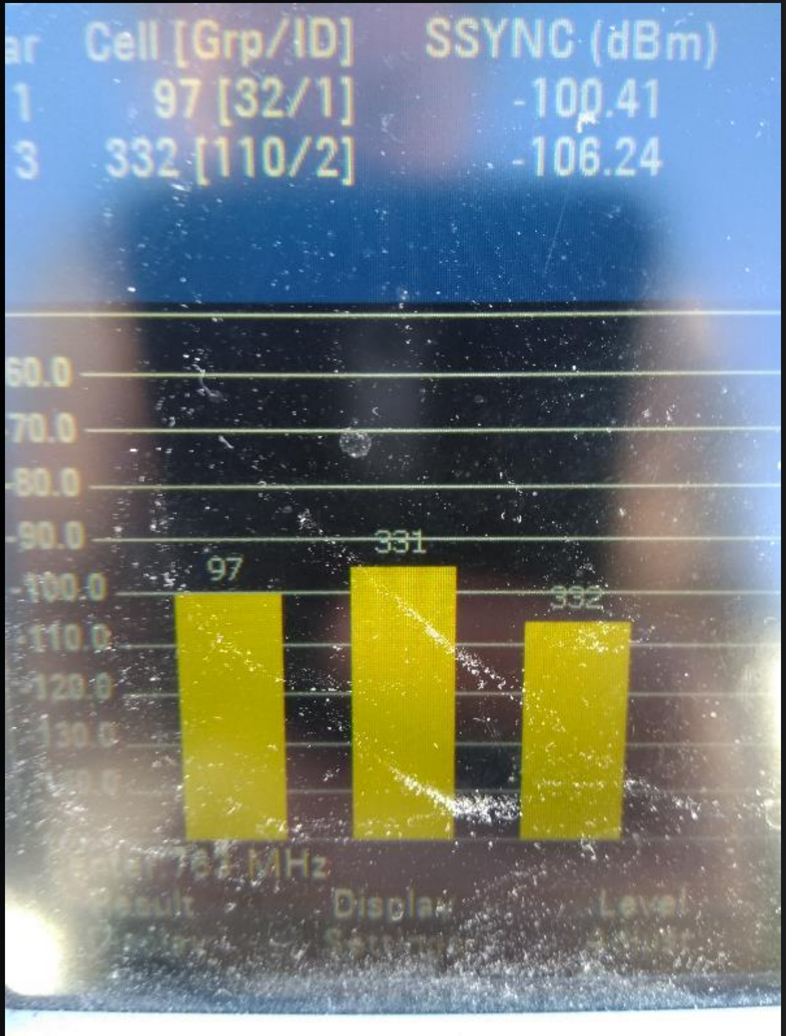
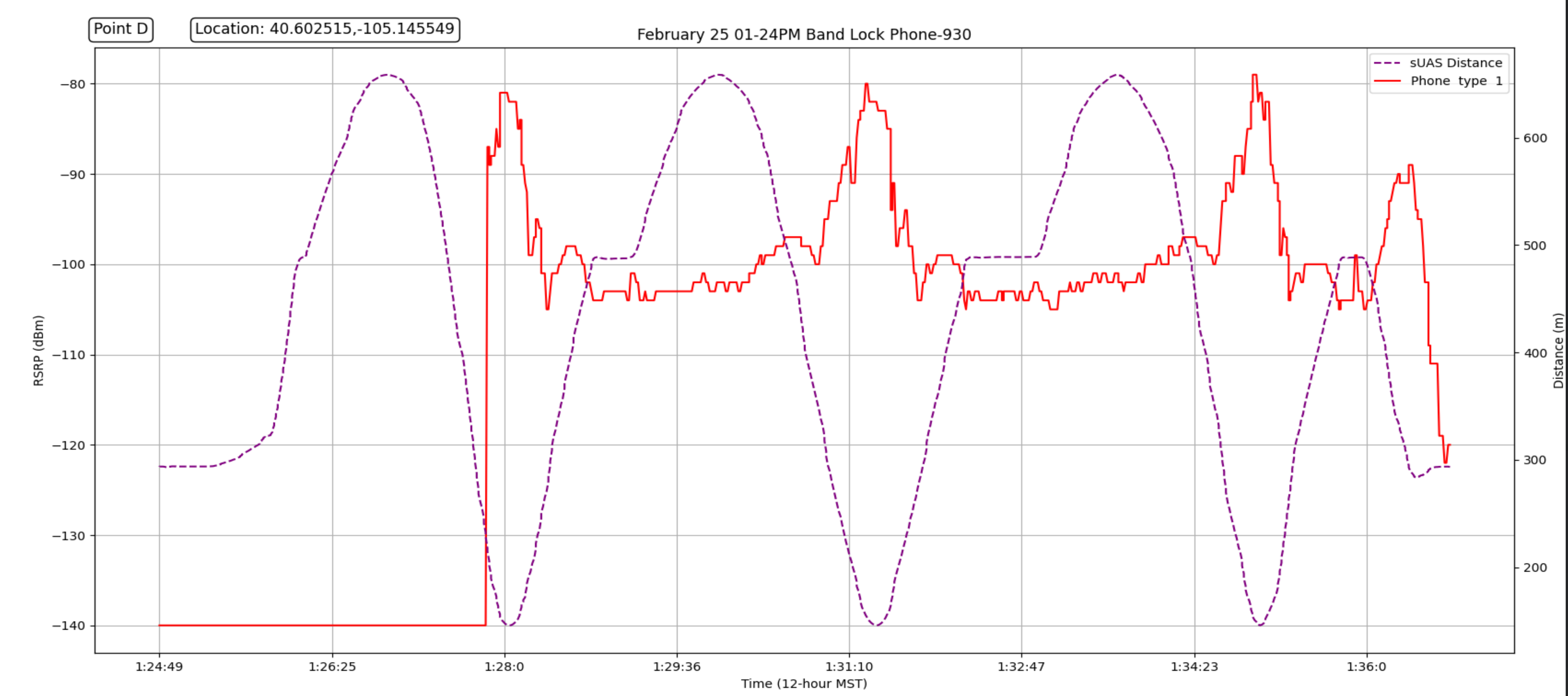


BAND LOCKING



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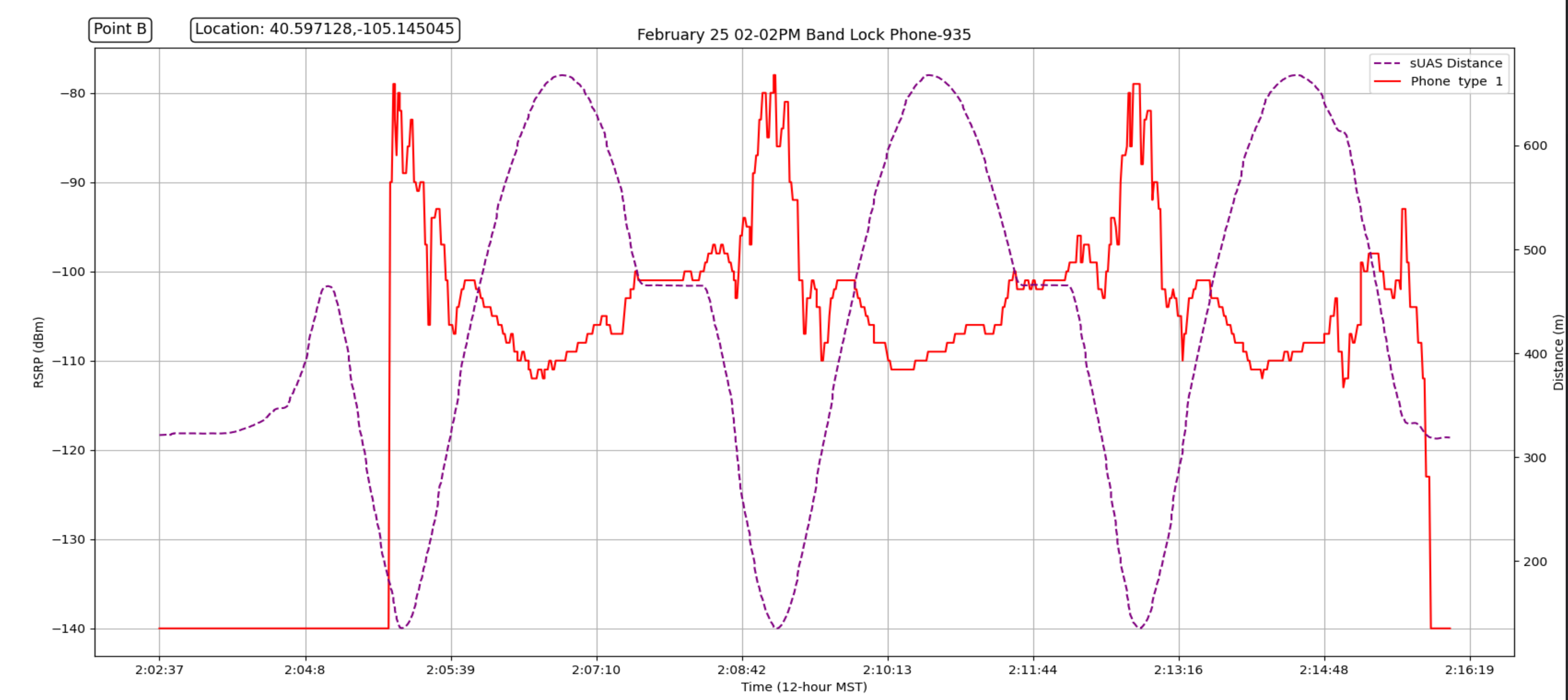

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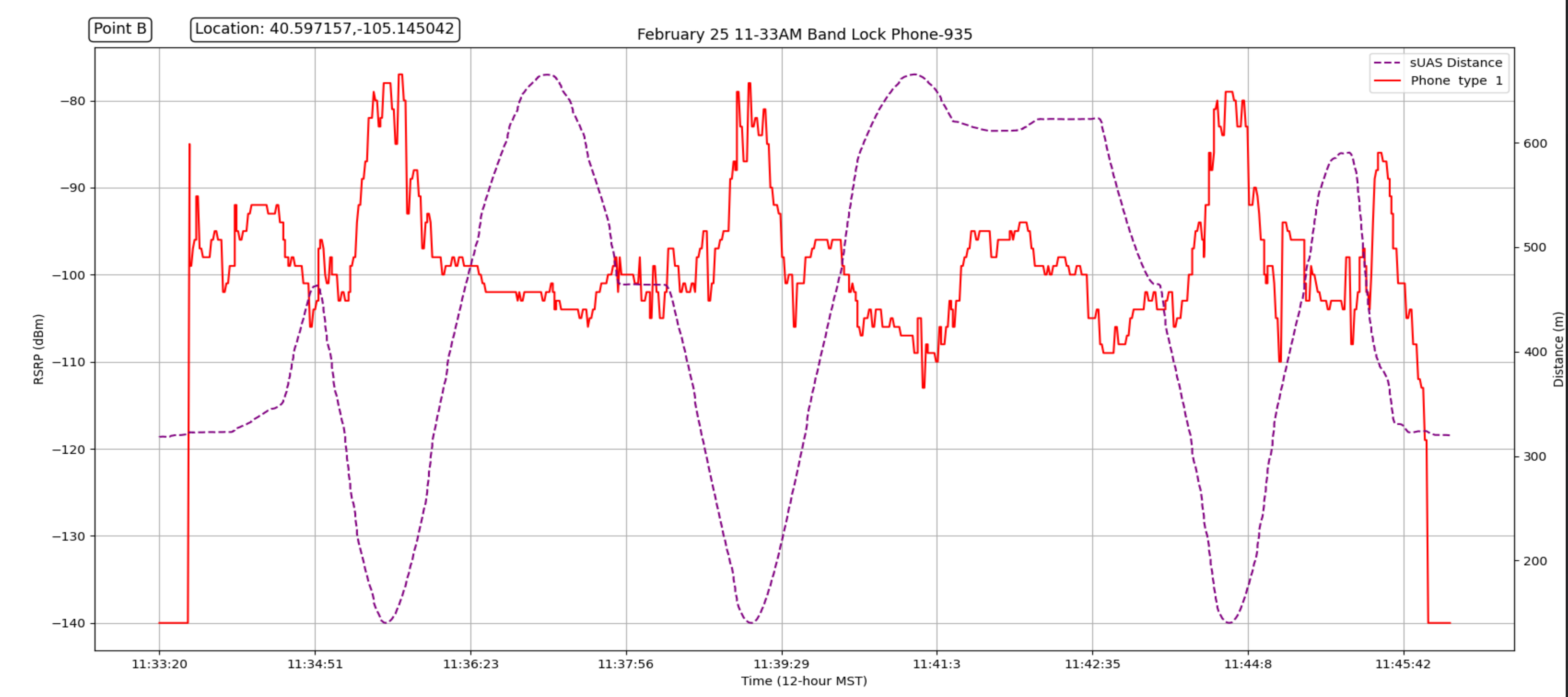

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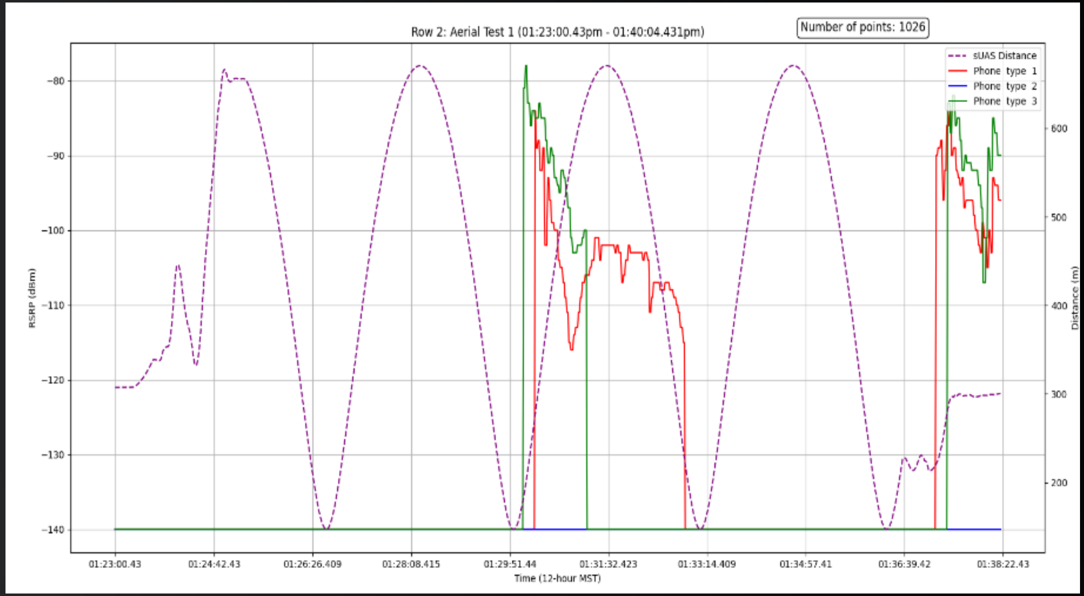
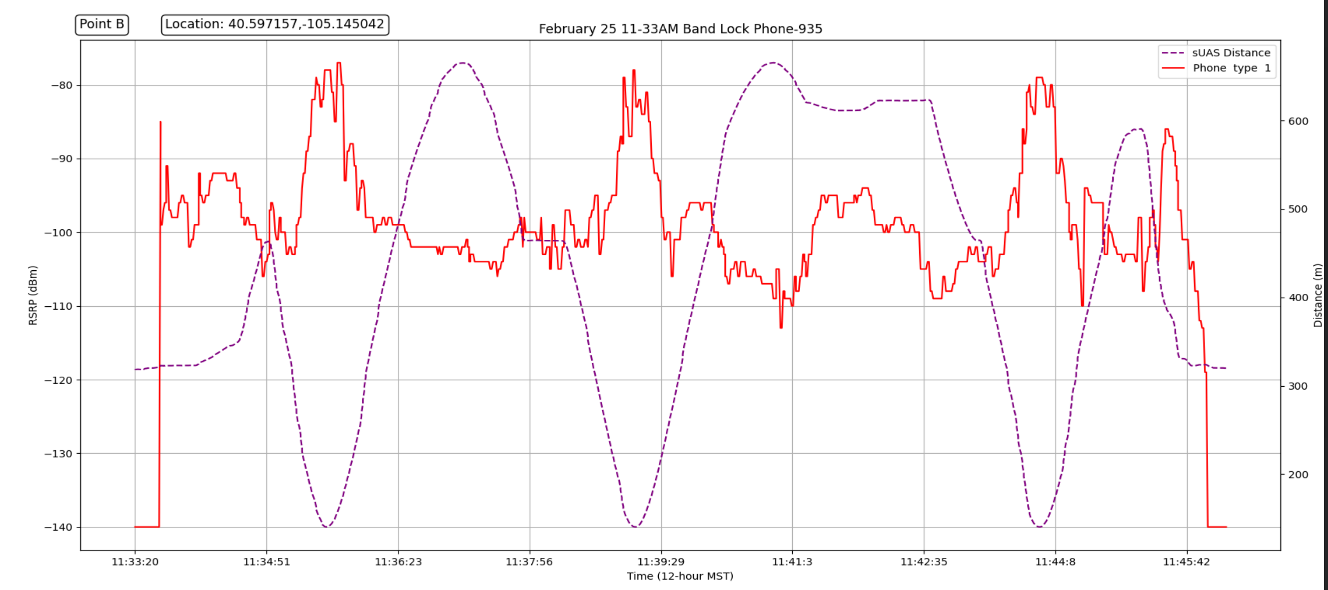
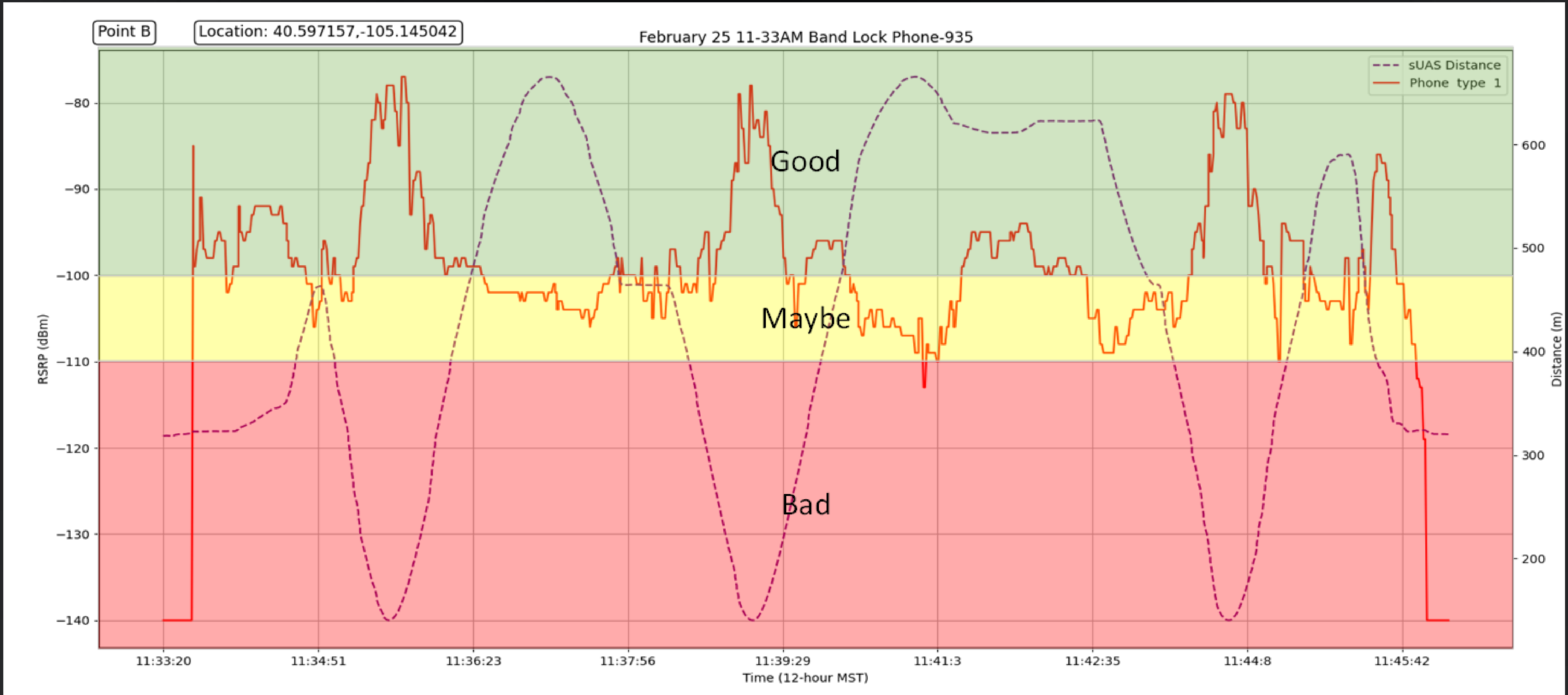




HIGHLY MOBILE DEPLOYED NETWORKS

BAND LOCKING



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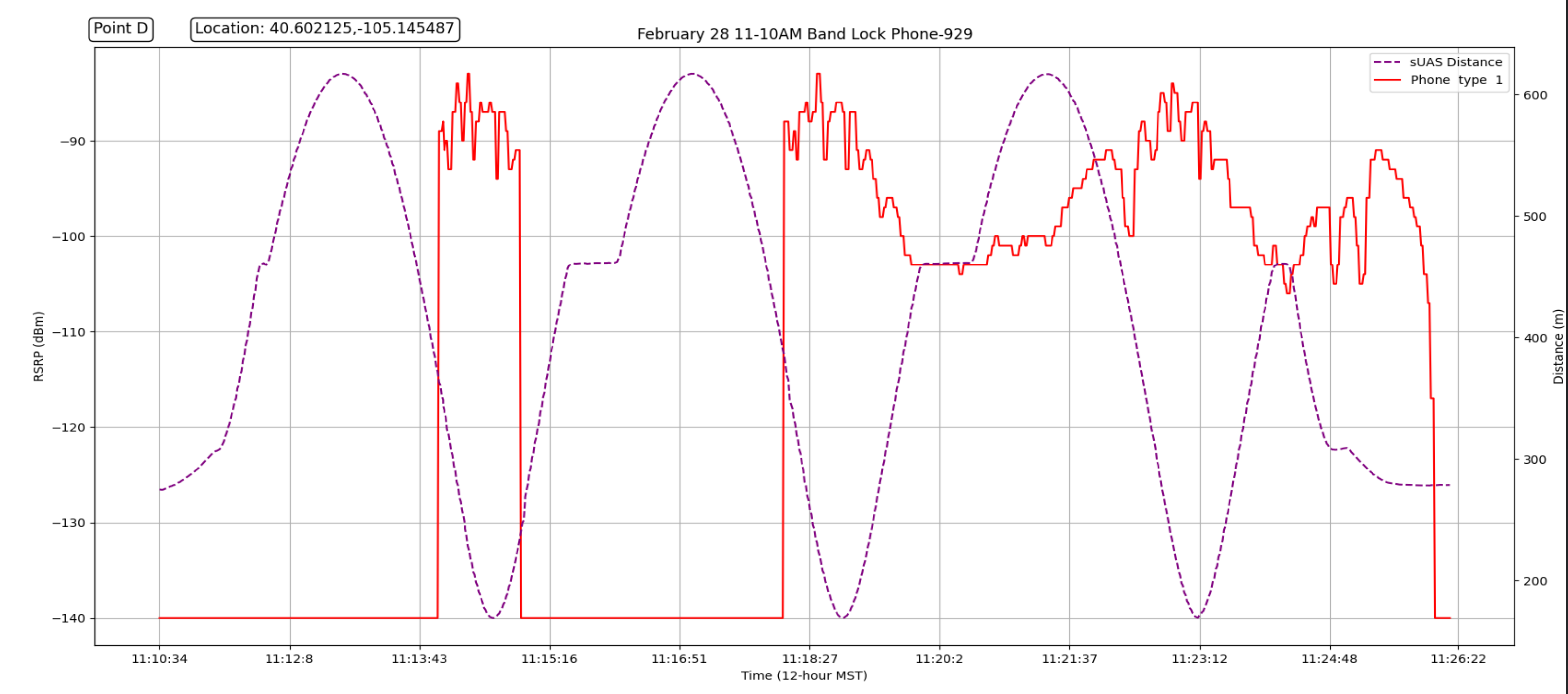
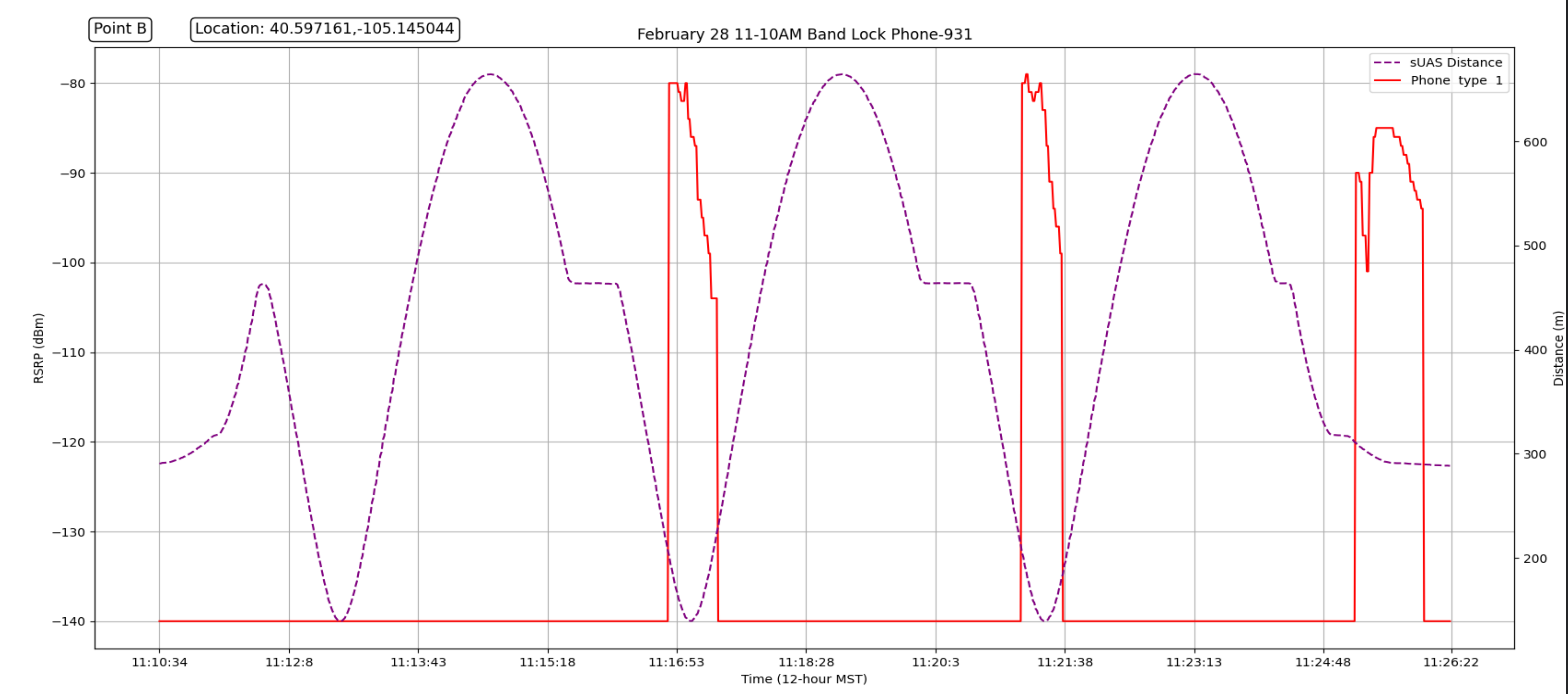


HIGHLY MOBILE DEPLOYED NETWORKS

BAND LOCKING



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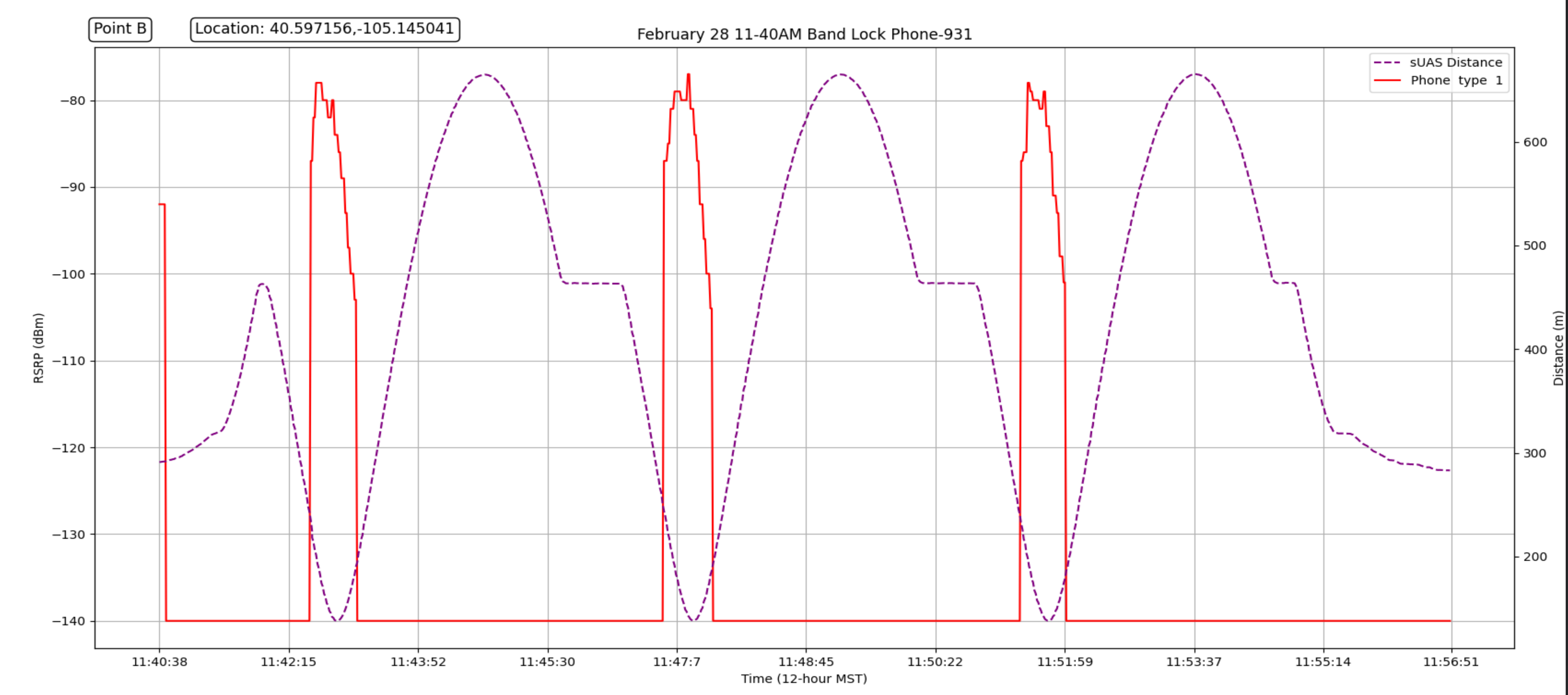

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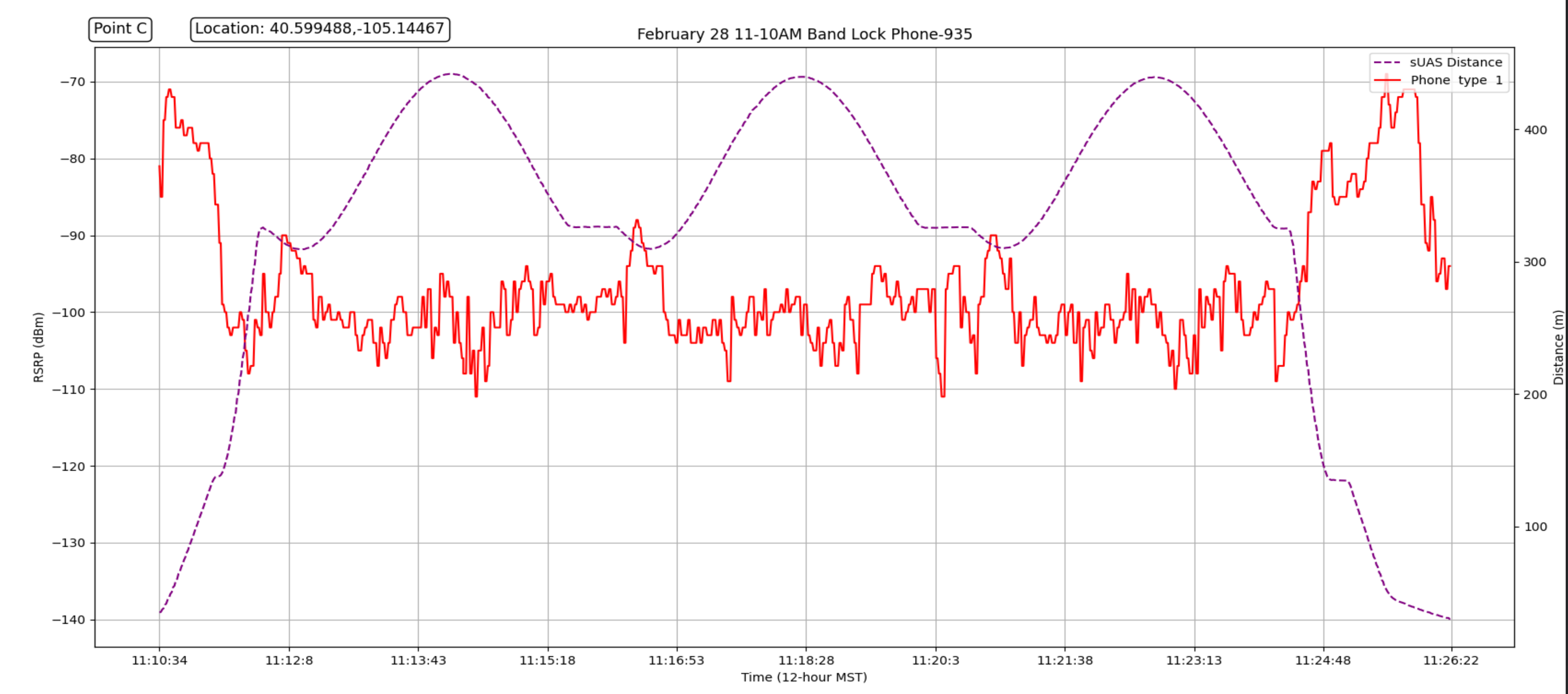

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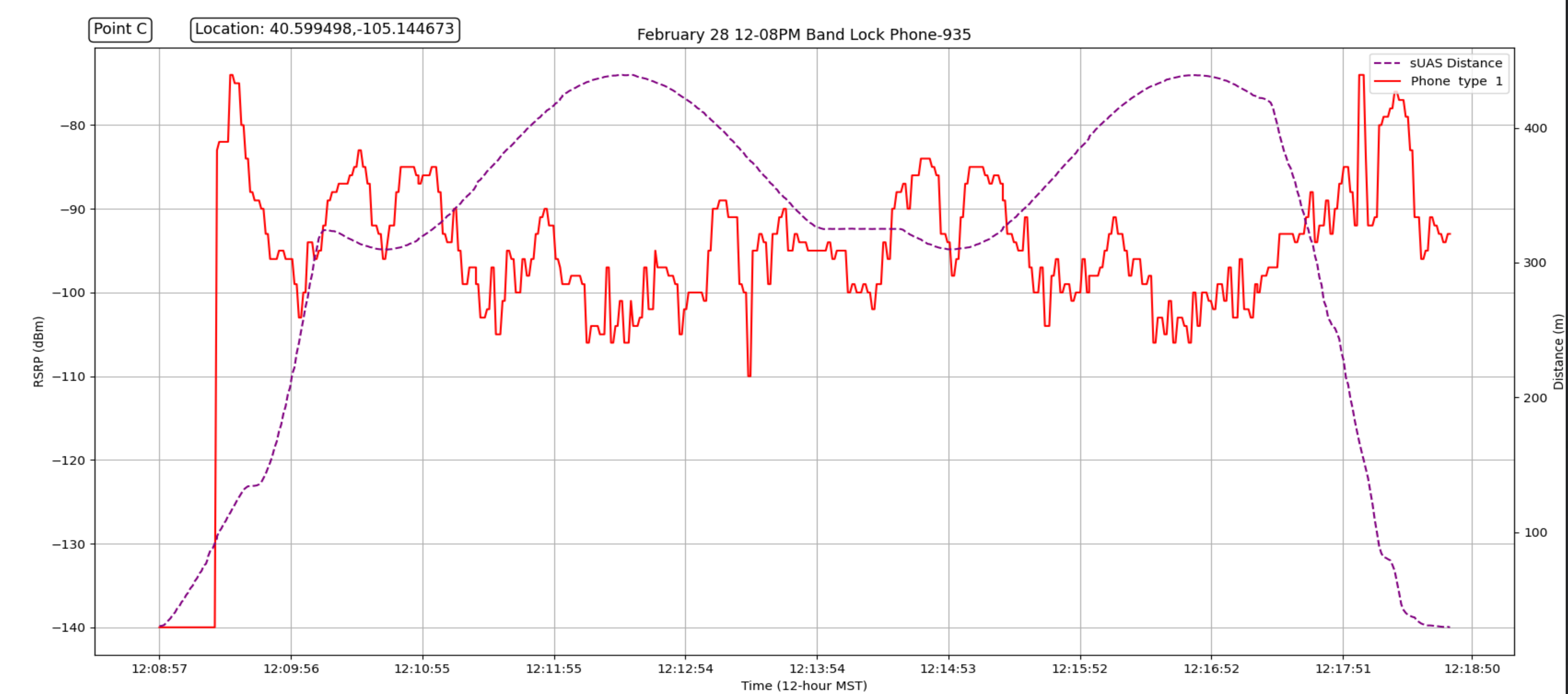

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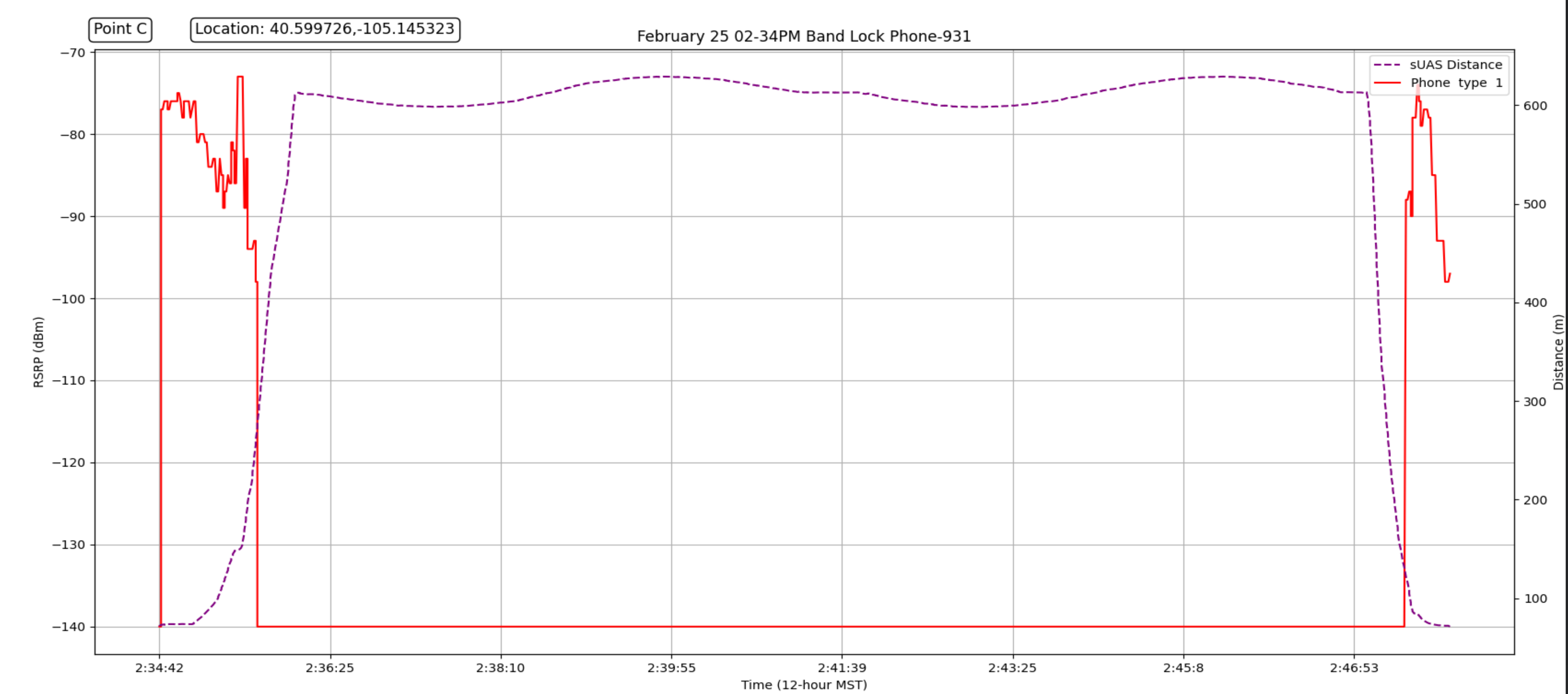

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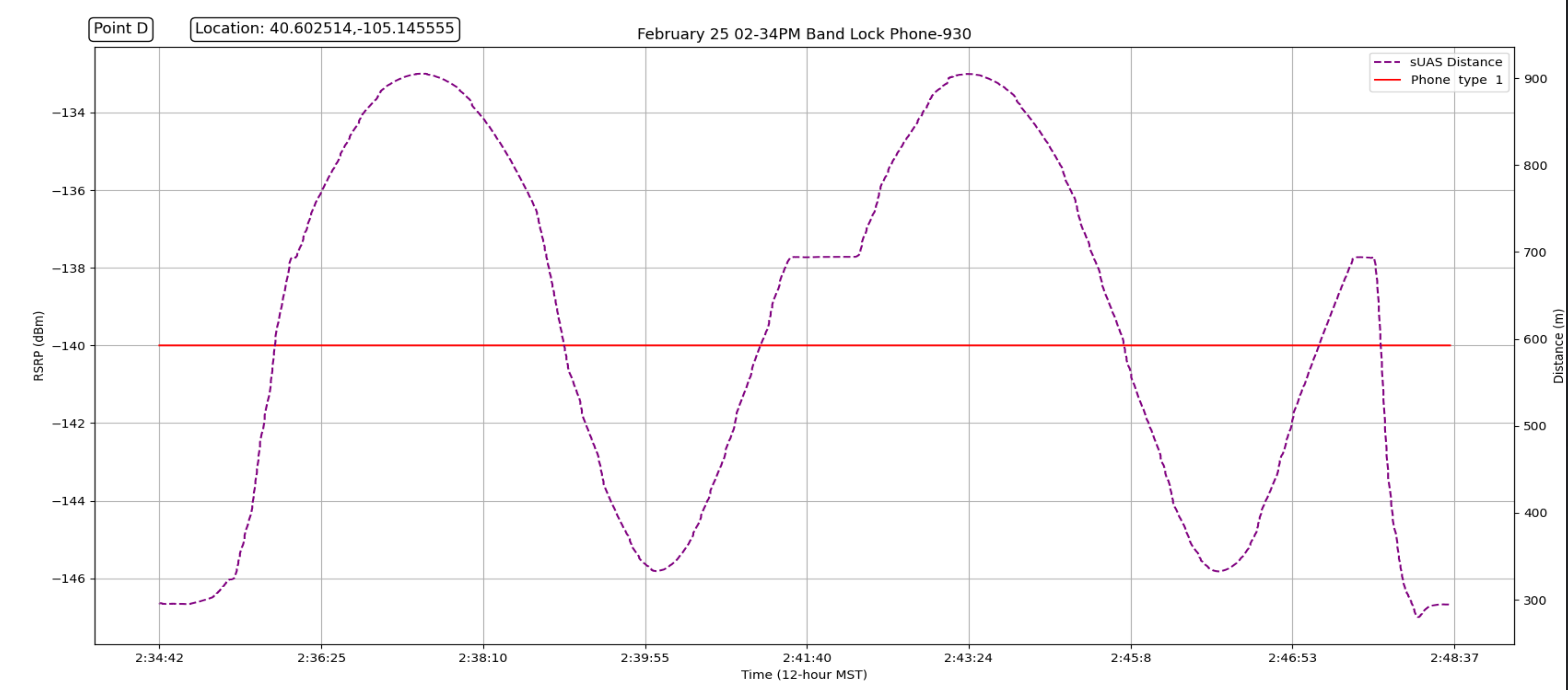


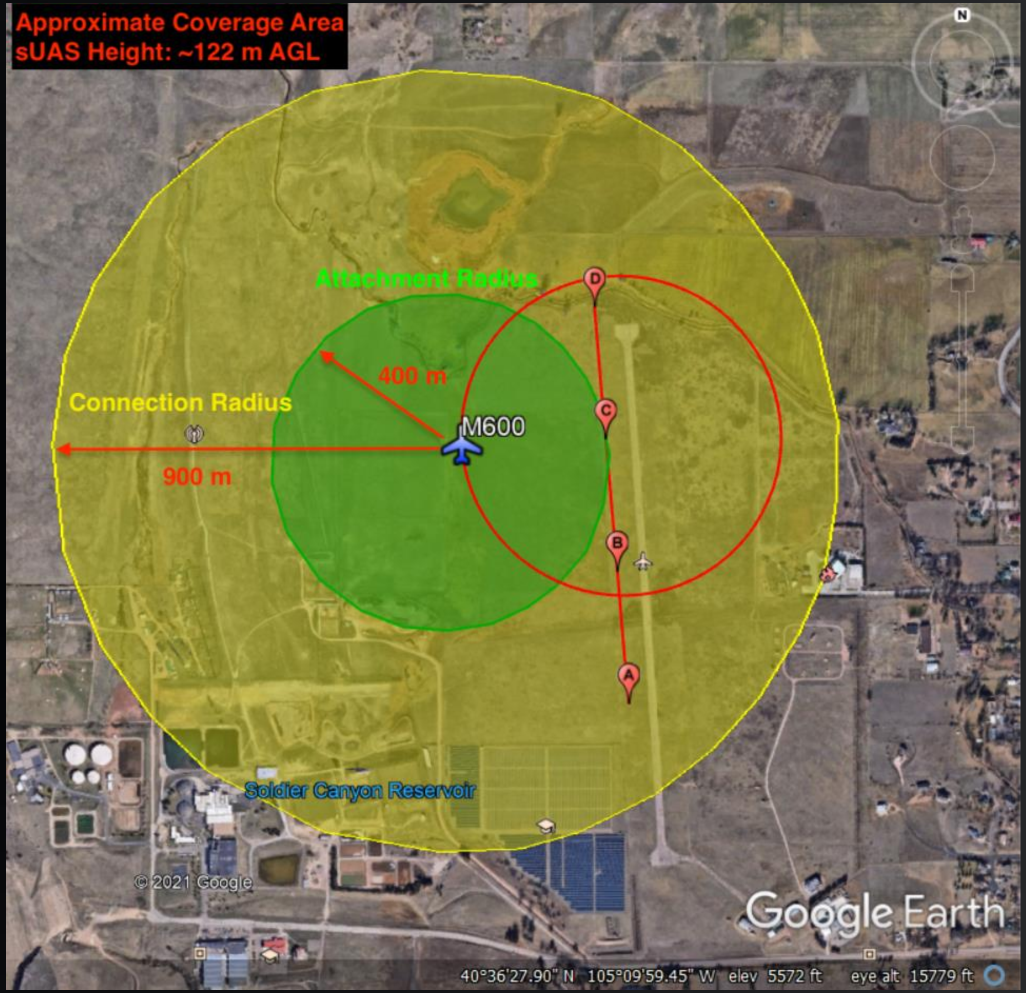
CONCLUSIONS AND RECOMENDATIONS

RESULTS

- Much more consistent connectivity with band locking, but could be better
- Higher noise floor present than previous tests, lead to less consistent connectivity
- Larger coverage footprint ~900 m

RECOMMENDATIONS FOR FUTURE DEPLOYMENTS

- Band locked phones
- Spectrum coordination
- eNodeB antenna gain
- Narrower bandwidth (5 MHz UL and DL)
- Replaceable parts for sUAS



RECAP

RECAP

Today we have gone over the Highly Mobile Deployed Networks project, the motivation for our aerial deployable system research, our test method, our results, best practices and recommendations for future operations. Once again, this research has been sponsored by the Department of Homeland Security Science & Technology directorate.

HIGHLY MOBILE DEPLOYED NETWORKS

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https://www.nist.gov/ctl/pscr/highly-mobile-deployed-networks

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THANK YOU

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