Deploying a Cost-Effective Method for Master Oscillator Lock for Broadcast Positioning System (BPS) Networks:

Developing technology to reduce the cost and complexity of BPS

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What is Leader-Follower BPS

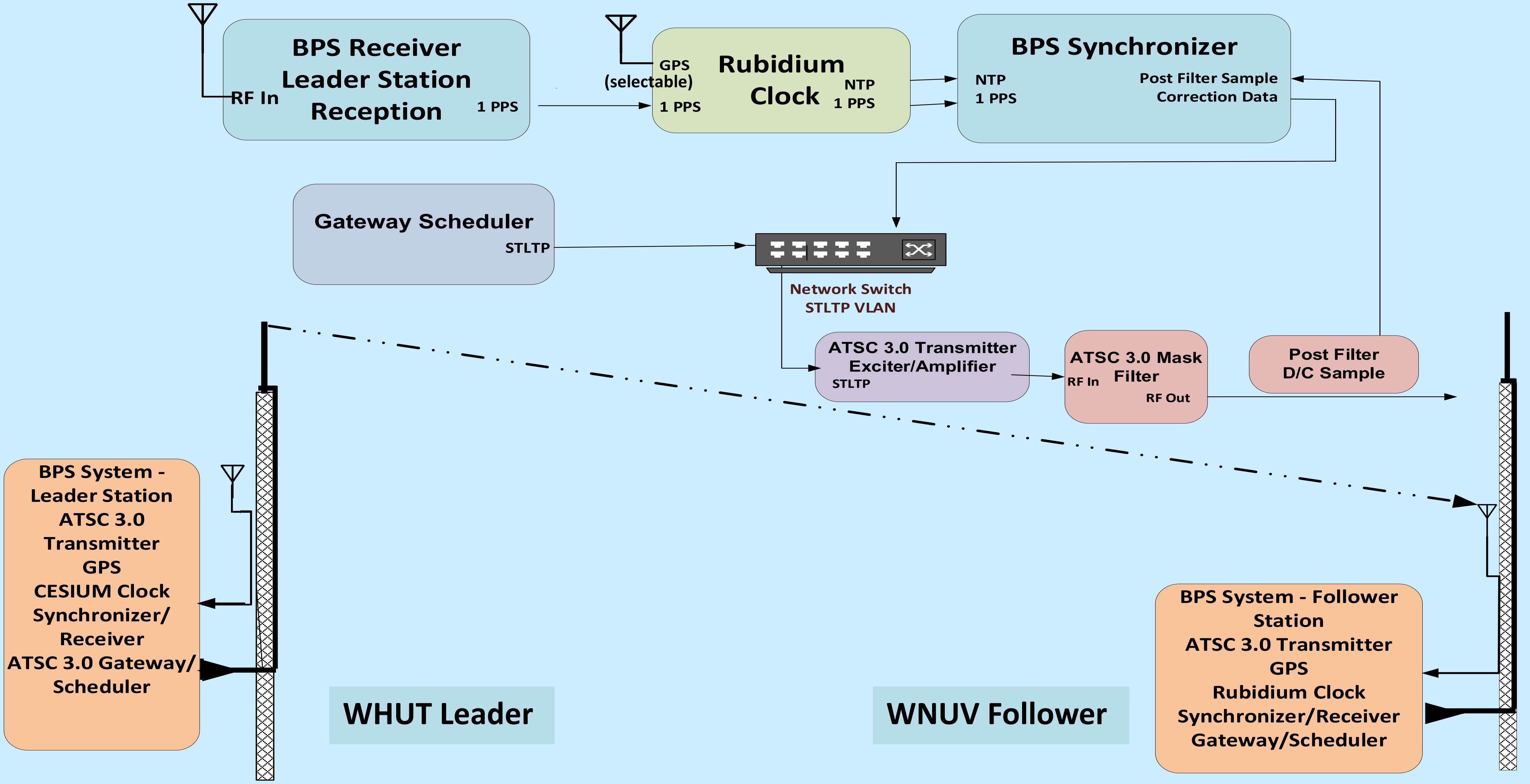
BPS is designed to operate when GPS is not available.

Leader station broadcasts a primary time standard.

Follower station receives this signal and locks its secondary time standard to the primary clock.

Leader-Follower technology could significantly simplify BPS deployment and reduce implementation costs.

BPS System Diagram Follower Station



Leader-Follower BPS

BPS requires a highly accurate, traceable timing signal.

- Referred to as a primary time standard.

Cesium atomic time standards are significantly expensive and complex.

- Cesium clocks will have holdover times of many weeks!

Rubidium clocks are significantly less costly but are a *secondary standard.*

- *Only good enough* enough for a day or two. They need to be referenced to a more accurate primary clock.

Cost comparison of between primary and secondary standards (Budgetary)

Traceable Time to lock (NIST)

- Dark Fiber and/or Satellite > $80K

Primary - Cesium Oscillator > $100K

Secondary - Rubidium Oscillator > $20K

Costs would further increase for required broadcast system redundancy

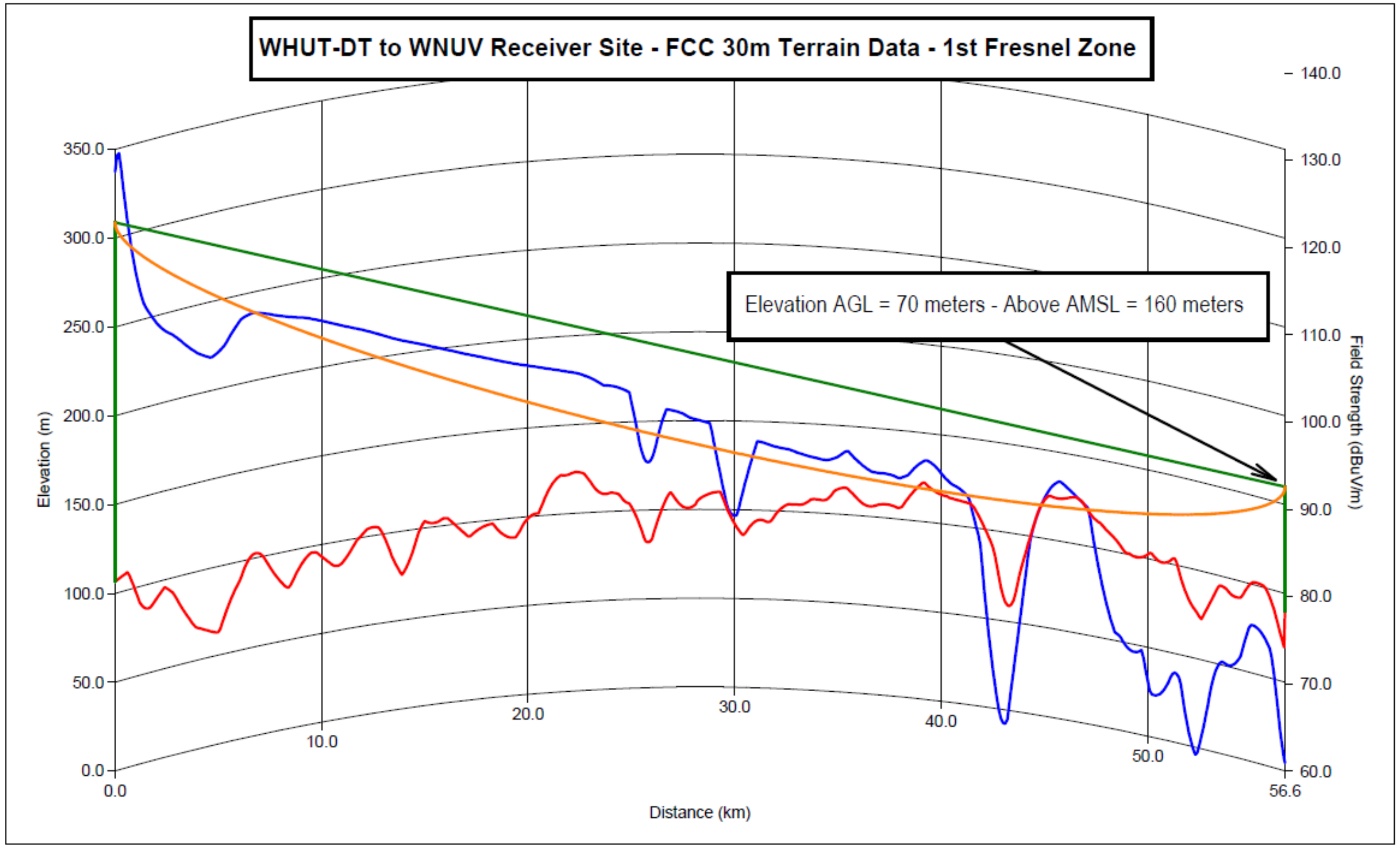
BPS setup at WNUV-TV ATSC 3.0 in Baltimore, MD

Typical BPS Equipment at a Transmitter site

Yagi Receive Antenna (to receive WHUT)

Terrain Path Profile WHUT to WNUV

WHUT (Leader)
Washington, DC



Start Latitude: 38-57-01 N
Start Longitude: 077-04-46 W

End Latitude: 39-20-09.10 N
End Longitude: 076-39-01.50 W

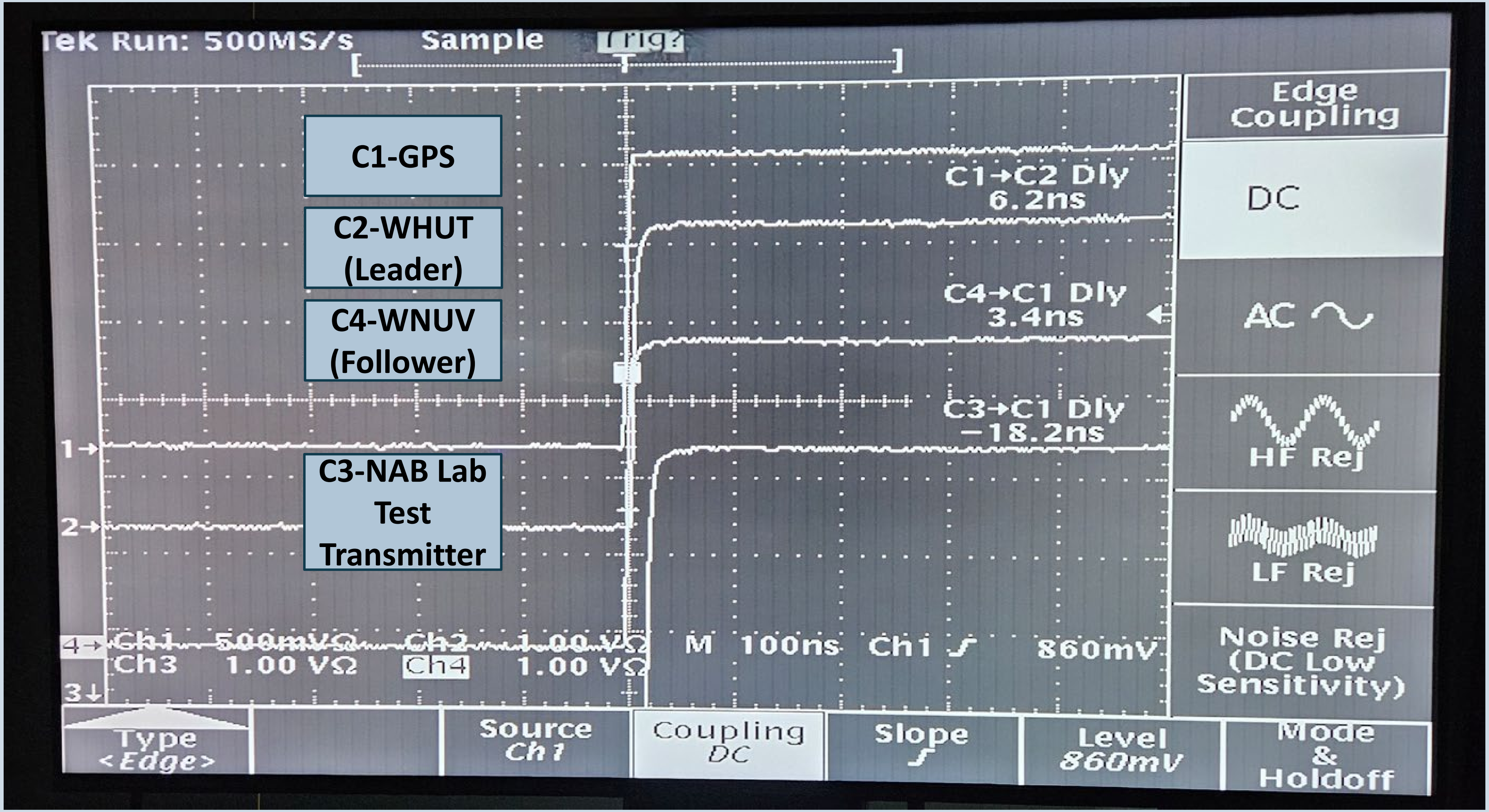
Distance: 56.64 km
Bearing: 40.77 deg

Terrain Profile
Field Strength

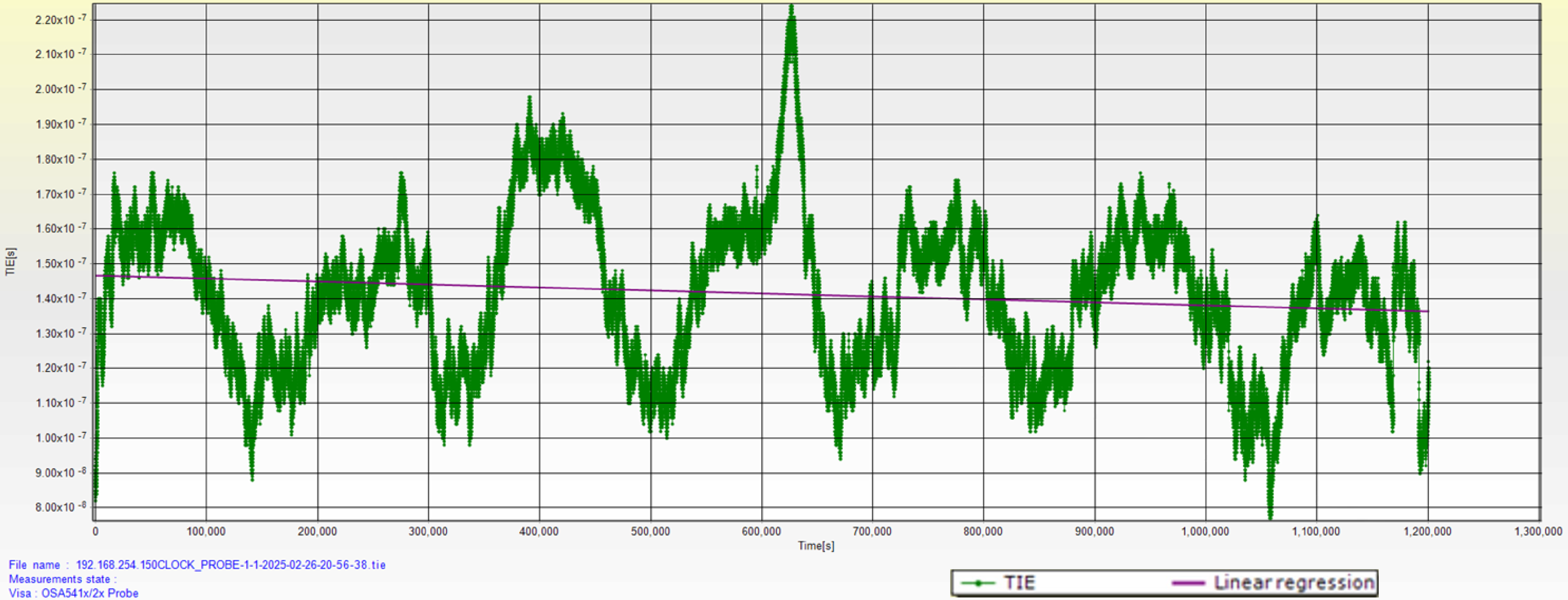
WNUV (Follower)
Baltimore, MD

Distance: 56.64 km
Bearing: 40.77 deg

Off-air reception at NAB Lab, Washington DC

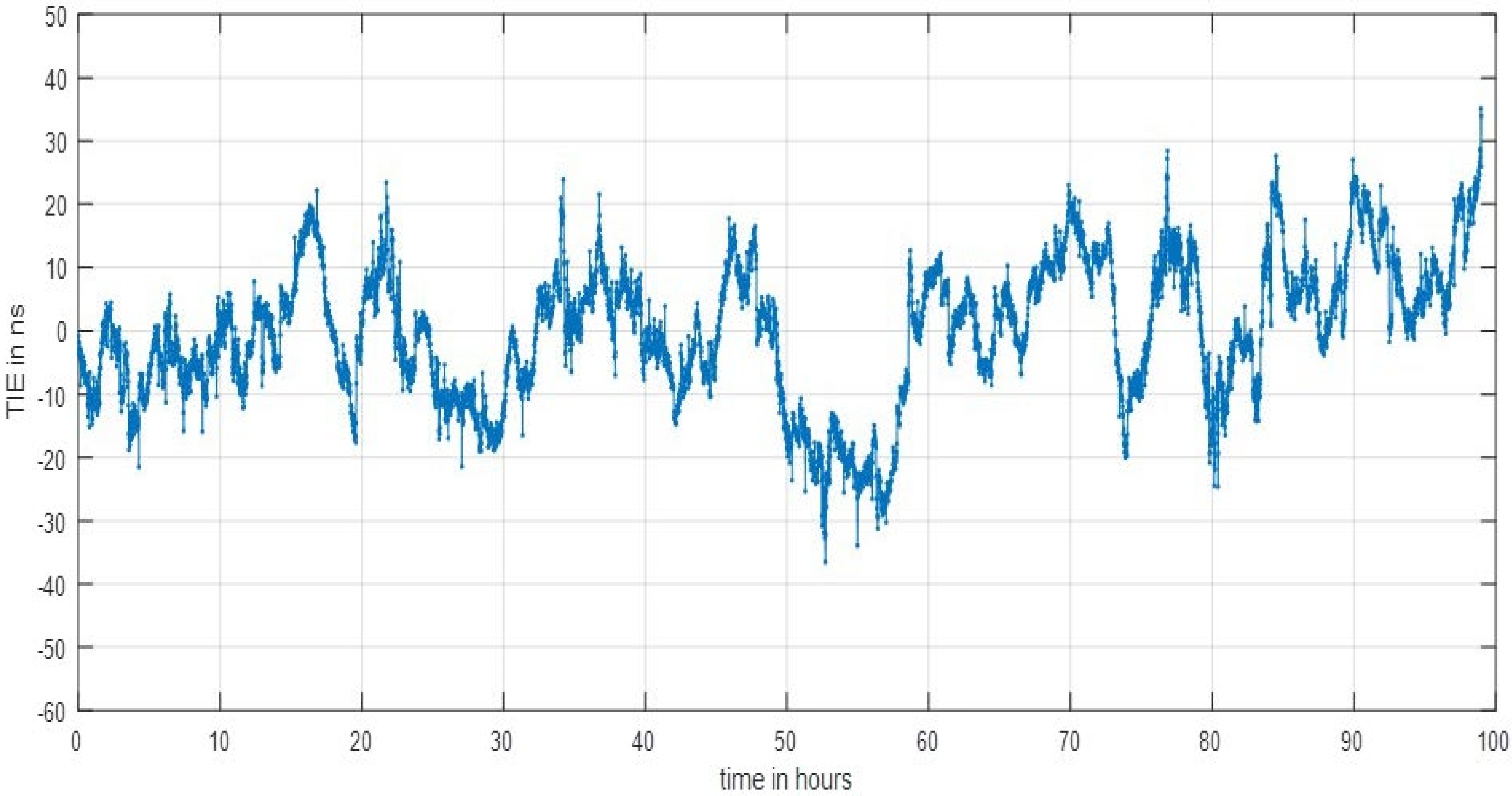


WNUV BPS Referenced to WHUT BPS (7day)



File name : 192.168.254.150CLOCK_PROBE-1-1-2025-02-26-20-56-38.tie
Measurements state :
Visa : OSA541x/2x Probe
Signal Test/unit : PPS
Reference signal : TimeClock
User comment : #Type:Phase #Title:ClockProbe1 #Adva Probe:ClockProbe #Adva MTIE Mask:G8271-1
Linear regression :Slope = -8.45E-015 ; OffSet =1.47E-007

WNUV Follower Referenced to WHUT Leader, (Referenced to GPS)



Results are encouraging

Leader-Follower technology works. It could become an important part of BPS deployment.

The time stability broadcast from the leader station is effectively synchronized at the follower station.

Time accuracy is within +/- 40 ns.

Further considerations for Leader-Follower system optimization

How can we further improve BPS accuracy and stability?

- Impact of differing received signal paths
- Equipment setup
- Path length, Path profile, Geographical and atmospheric considerations.

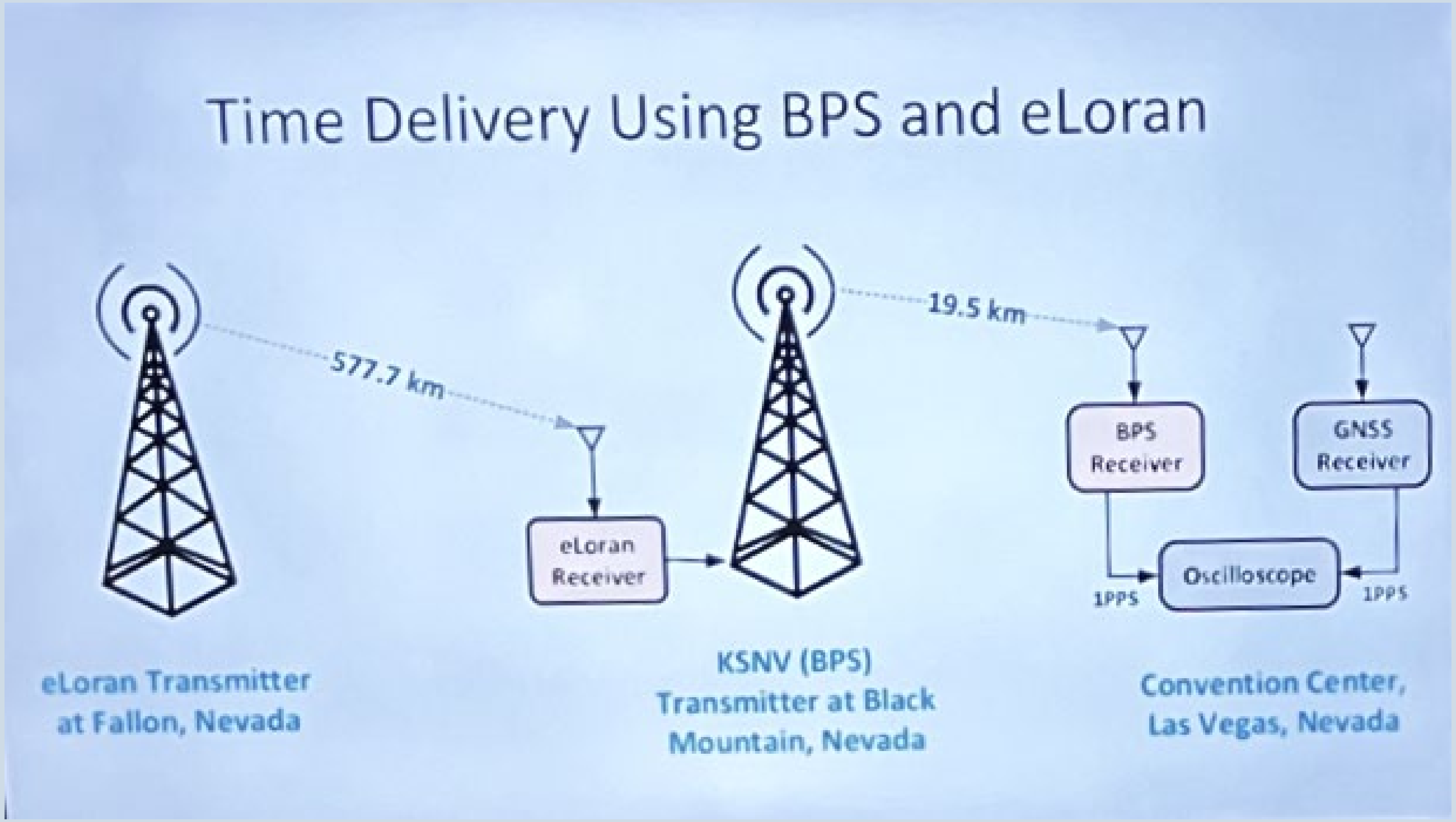
Determine practical geographical limits of separation.

- Maximum operational separation between Leader-Follower stations.

Testing takes time. We want to analyze drift over many weeks.

Need to develop system monitoring and management as we implement a national BPS service.

Other Related Work: BPS/eLoran Demonstration @NAB 2025

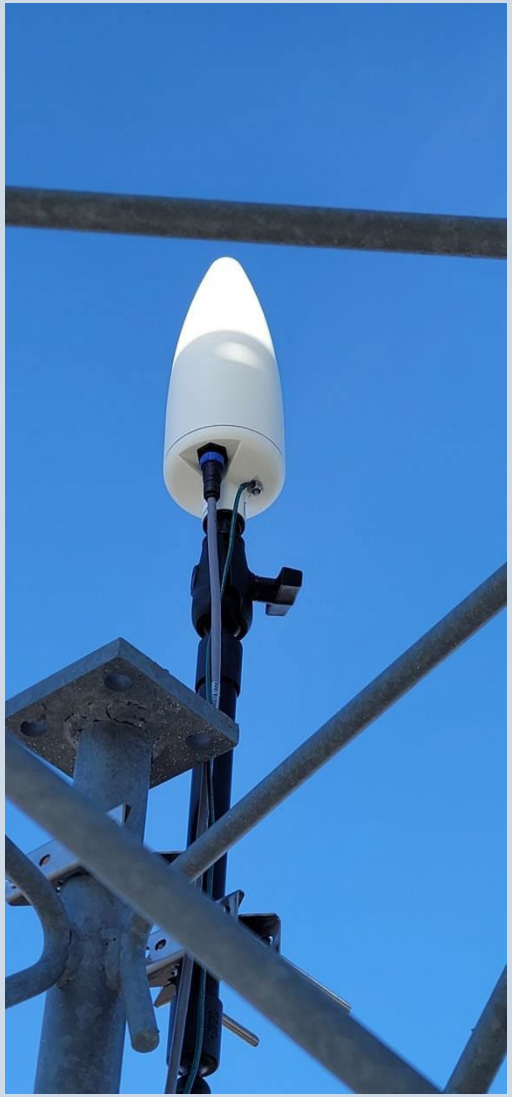


Receiving eLoran from Fallon, NV (225klm)

- 1pps output driving BPS capable ATSC 3.0 transmitter
- Receiving the BPS signal at LV Convention Center
- Reference the BPS signal to GPS
- Comparing the BPS output

KSNV TV Black Mountain, Las Vegas, NV

Transmitter Site, Black Mountain, Las Vegas NV



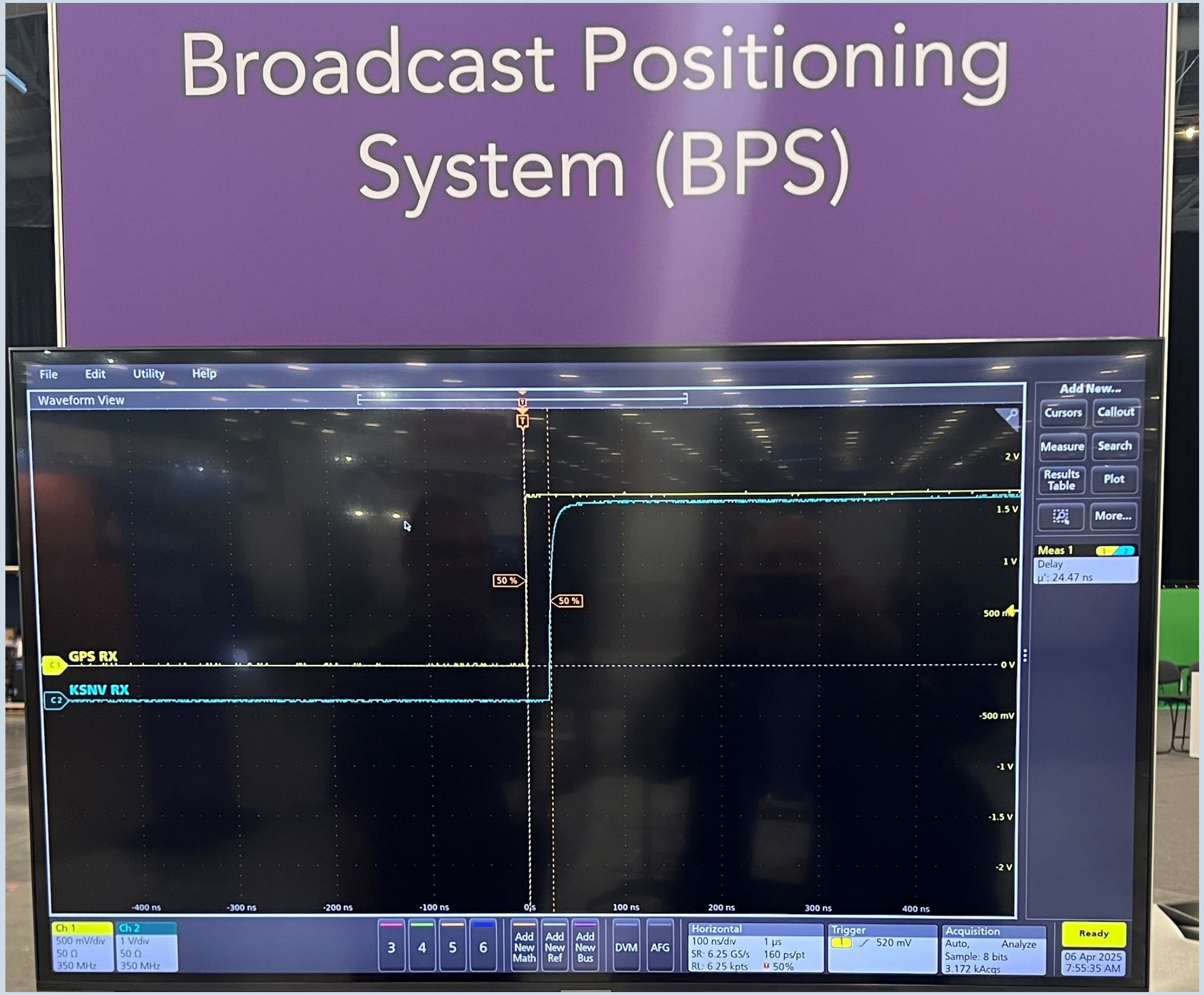
BPS-eLoran Demonstration

Demo showed very good time transfer. (+/- 25 ns)

….BUT

eLoran may not be practically suitable for Mobile/Cellphone form factors

- Increased RF noise at 100 kHz
- 100 kHz vs VHF-UHF Television Broadcast bands. (Laws of physics)



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Charles Schue – UrsaNav (eLoran-BPS NAB Demo in Las Vegas)

Questions:

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