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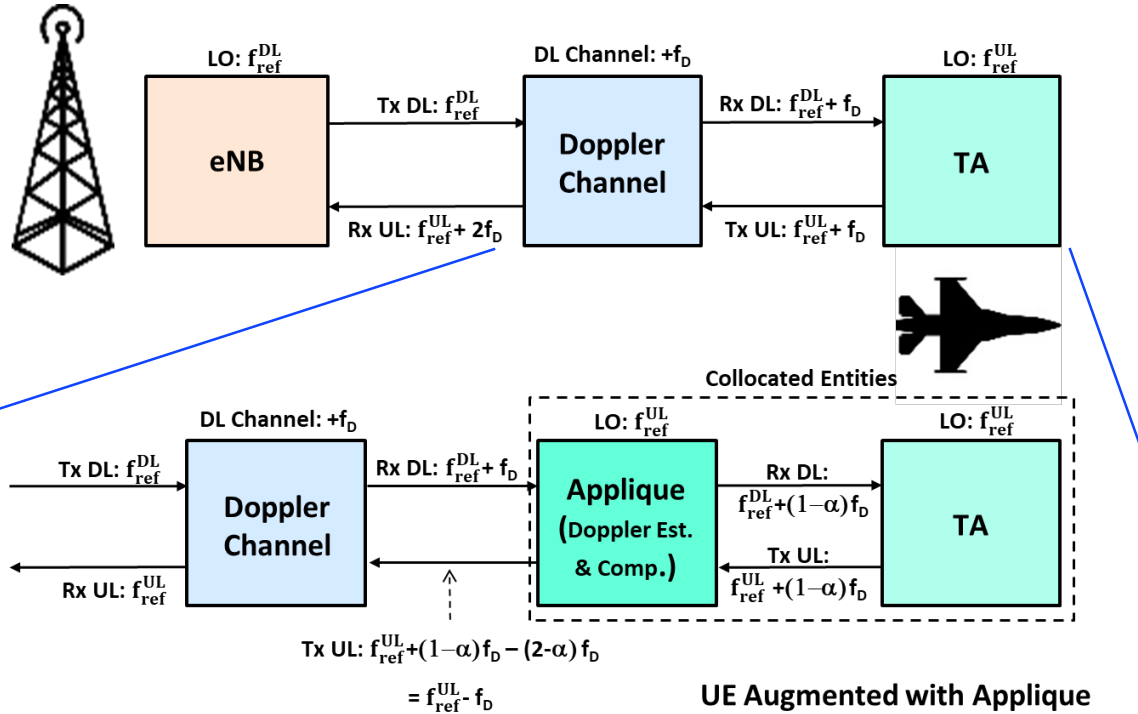
# Cellular Range Telemetry Network: Field Test Results Overview

Eric Beck, Shobha Erramilli, William Johnson, Achilles Kogiantis,  
Jenny Maung, Kiran Rege, Anthony Triolo and Jeff Young

May 14-16, 2019

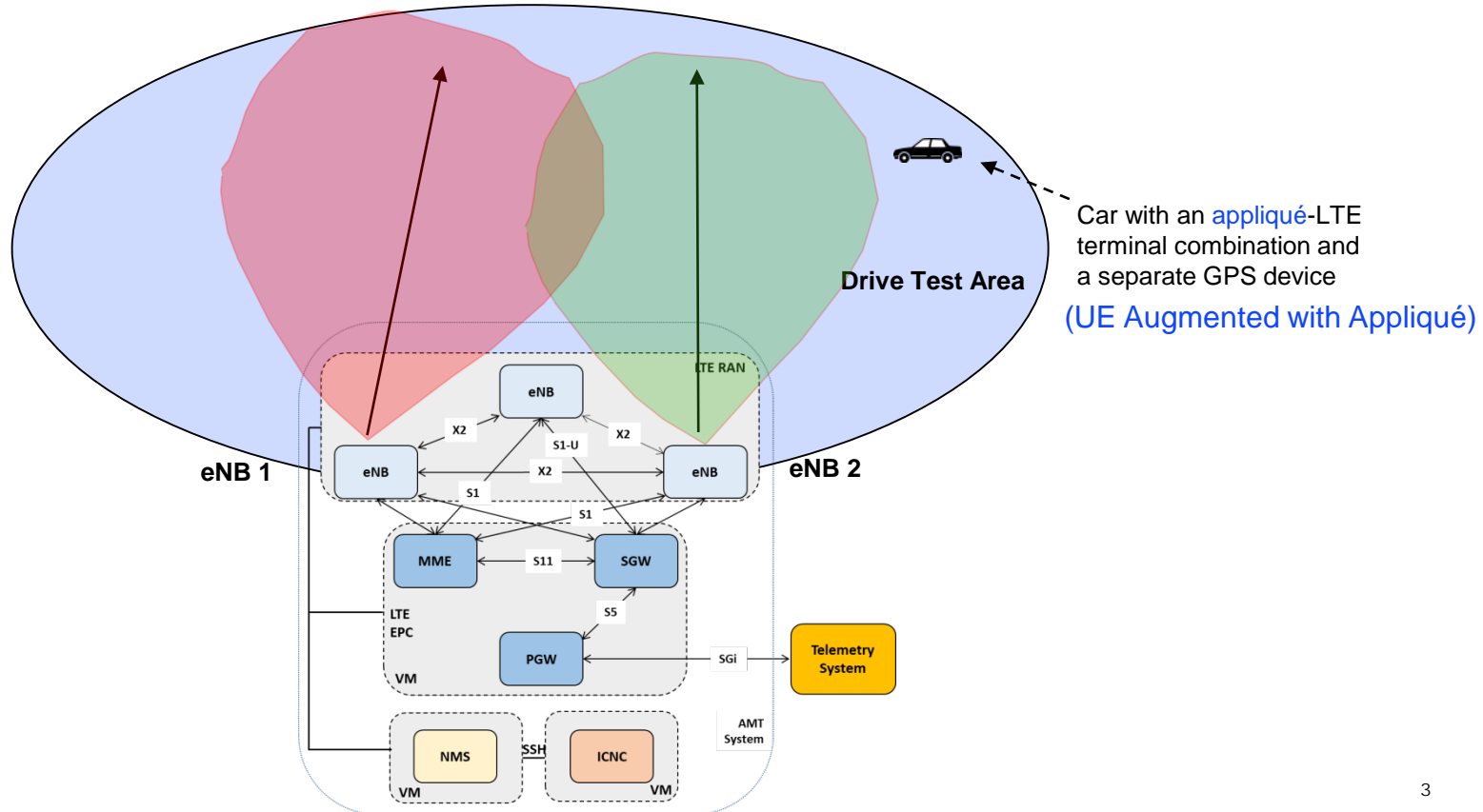
# Addressing High Doppler Shifts in **Aeronautical Mobile Telemetry (AMT)**

## - The Perspecta Labs Solution



The terminal-applique' combination has been tested extensively in the lab.

# The Field Test Setup – Ground Test



# CeRTN 4G LTE base station site installation

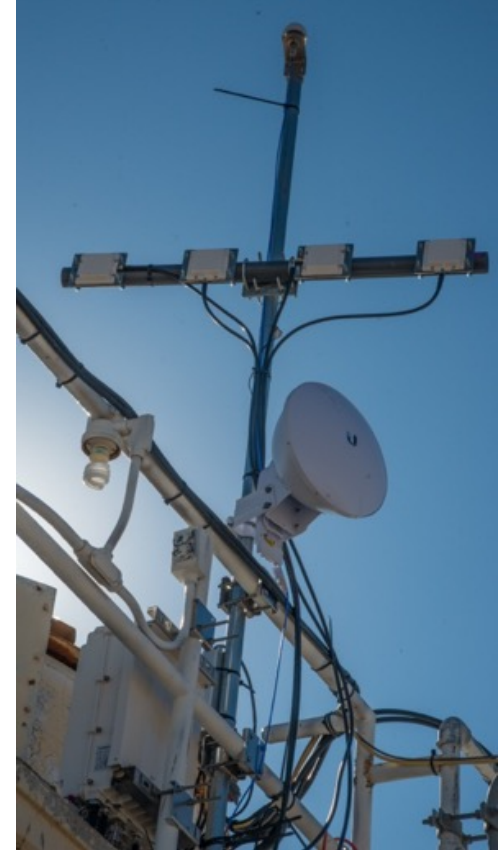
eNB1



eNB1



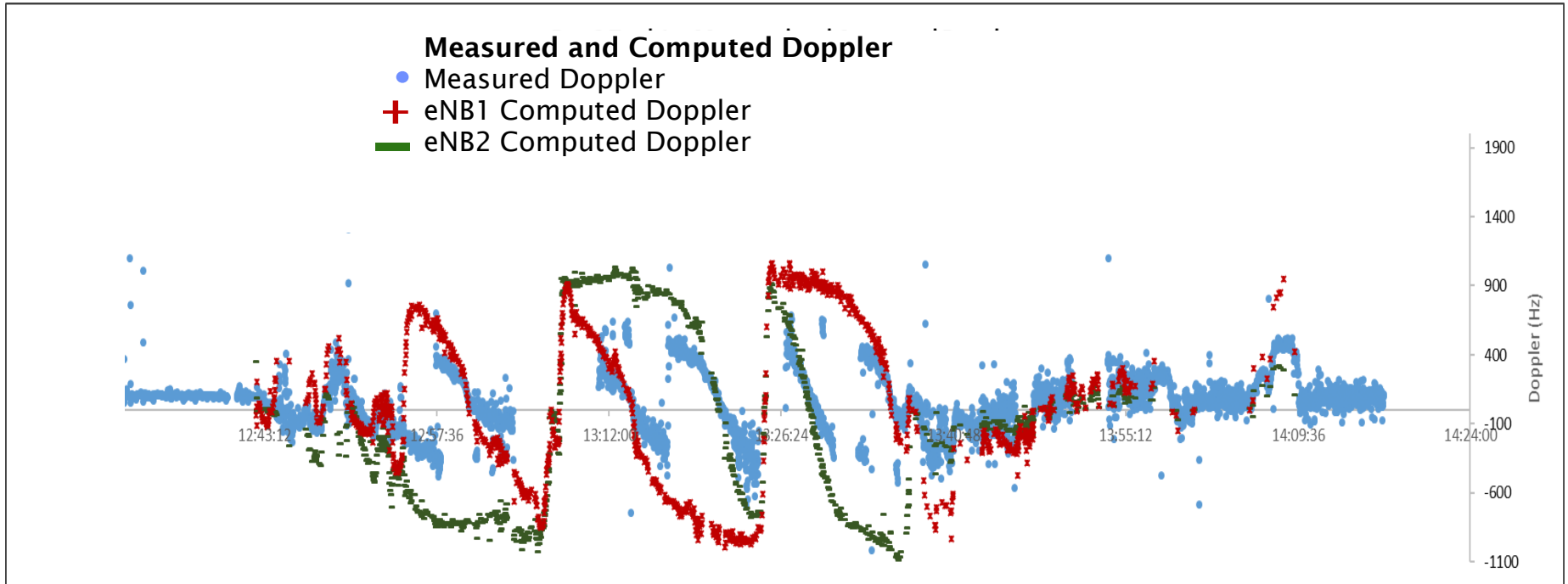
eNB2



Parameter	Value
Operating Frequency	Lower C 4.4-5.0GHz
Bandwidth	20MHz
Duplexing Mode	TDD
eNB Antennas	4Rx, 2Tx
Patch Antennas	Broad Beamwidth
Test Article Antennas	2Rx, 1Tx

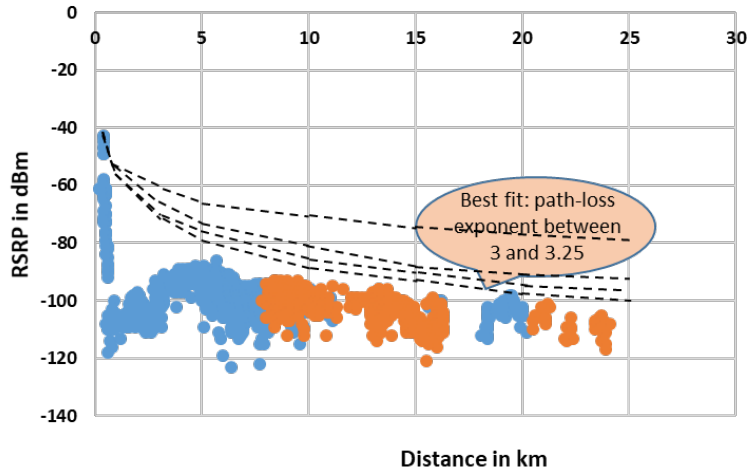
# Applique Doppler Shift Tracking

- Tracking during Handover events
- Computed Doppler generated from GPS readings of the TA
- Measured Doppler estimated and applied at the applique

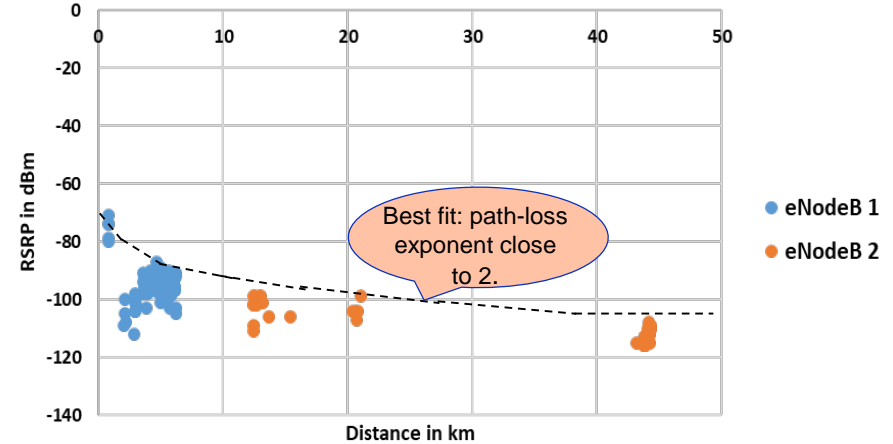


# Field Test Results: Distance-RSRP Relationship 1

## Distance-RSRP Relationship: Day 3, Track 1

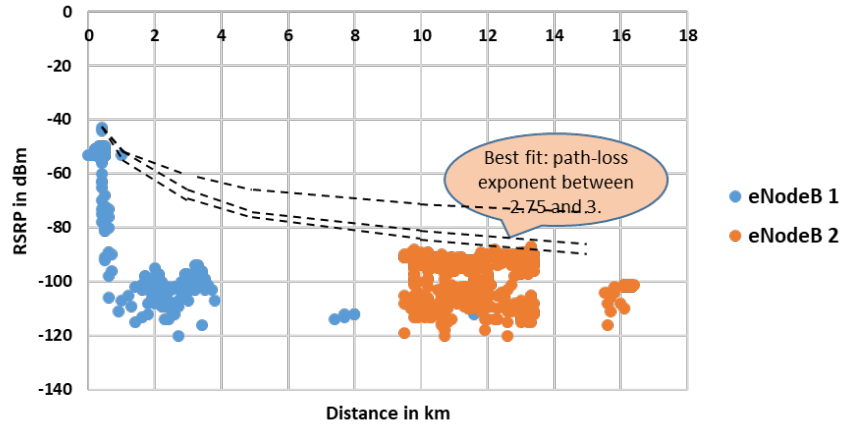


## Distance-RSRP Relationship: Day3, Track 2

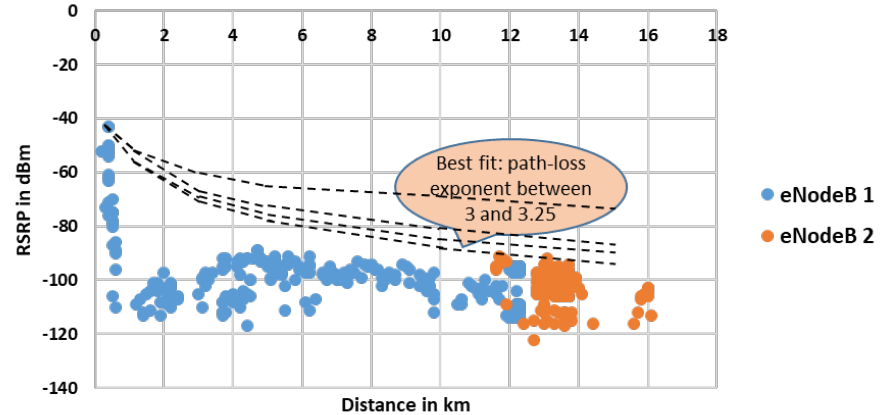


# Field Test Results: Distance-RSRP Relationship 2

## Distance-RSRP Relationship: Day 4, Track 1

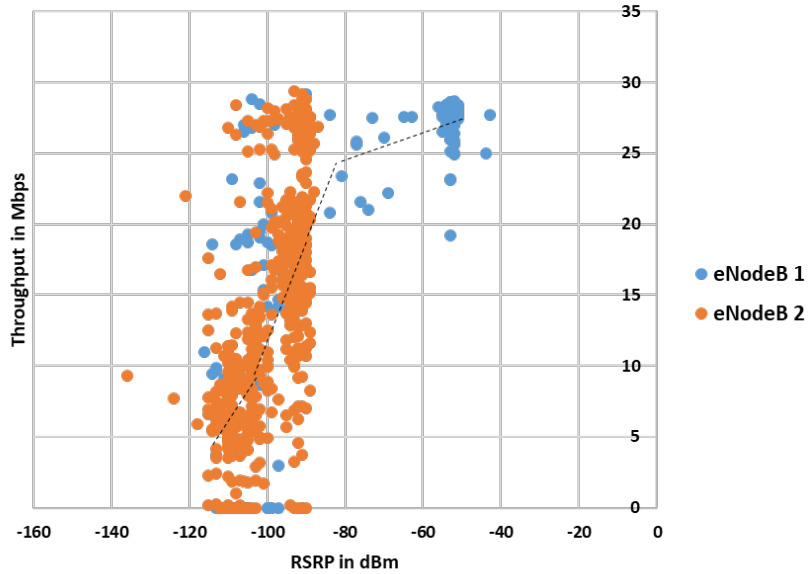


## Distance-RSRP Relationship: Day 4, Track 2

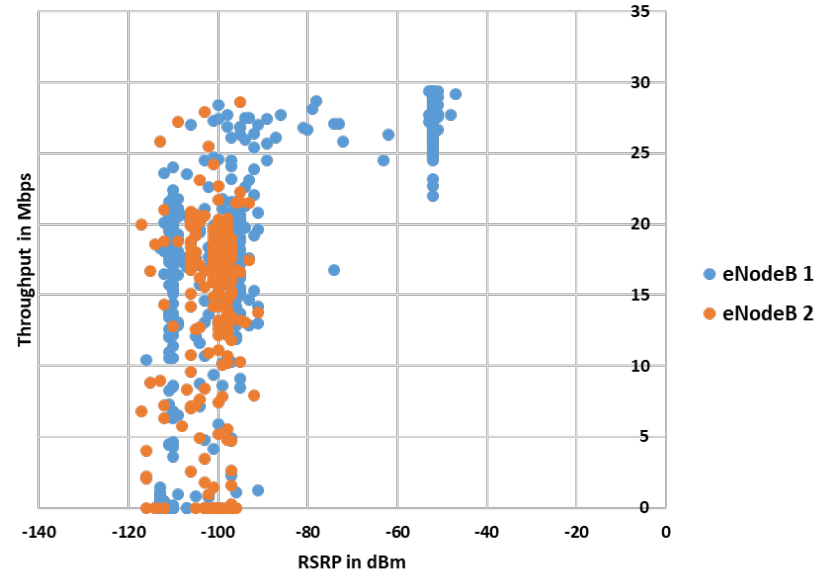


# Field Test Results: Distance-Throughput Relationship

RSRP-Throughput Relationship: Day 4, Track I

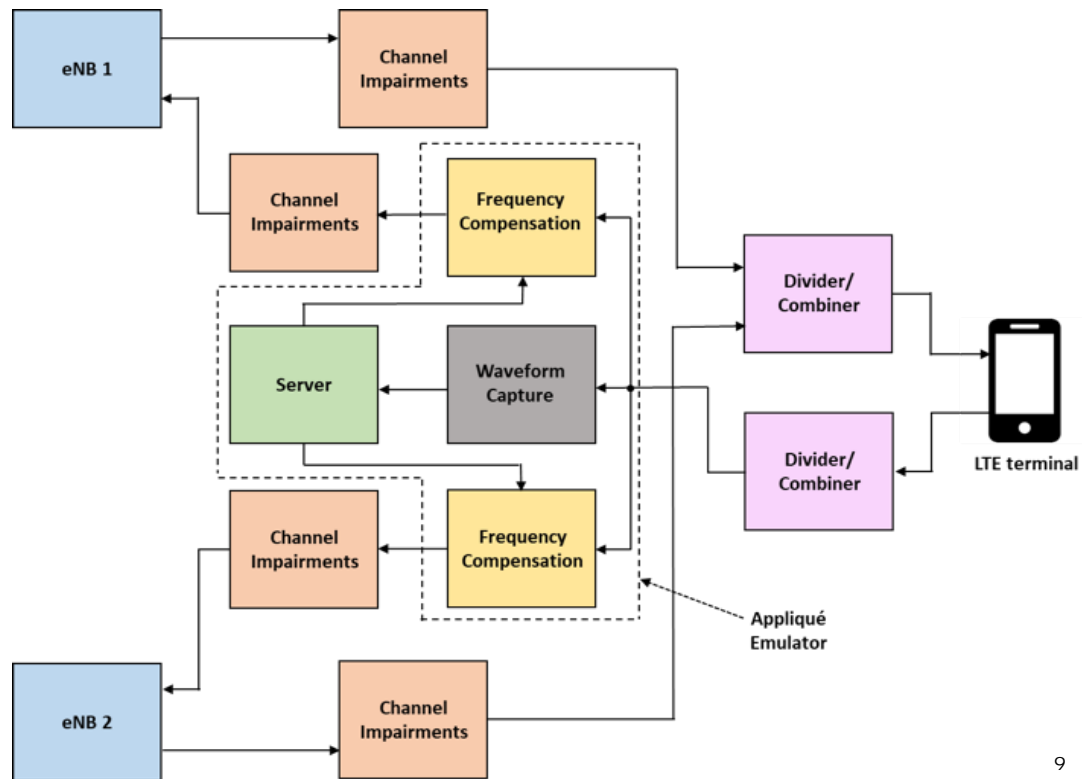


RSRP-Throughput Relationship: Day 4, Track II



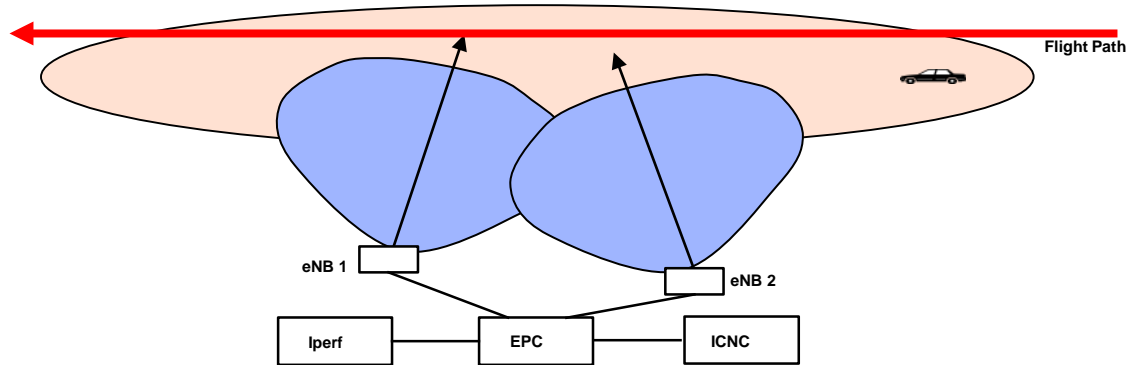
# Laboratory Flight Path Emulation

- Reproduce an accurate emulation of an actual flight plan in the lab:
- Two eNBs, one TA: Doppler, Gain, and Distance from eNB calculated from flight plan and played back in real time



# Flight Plan emulation in lab: ICNC Output

- Straight Flight East to West

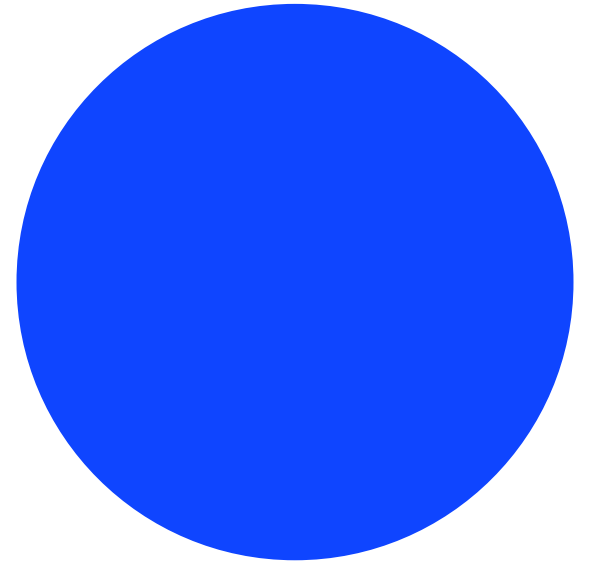


## Conclusion

- Throughout the field test, the **appliqué** was able to estimate and compensate for the Doppler shift associated with the serving eNB **and helped maintain the LTE link.**
- Propagation analysis complicated by several factors: **(formed multiple sub-bullets instead)**
  - Presence of shadowing
  - lack of a large number of independent **measurements**
  - TCP/UDP iperf issues – TCP **can result in** slow-start in case of packet losses.
- **Some conclusions can still be drawn from the available data:**
  - Fitting a power-law curve to the highest observed RSRP levels in the distance-RSRP graphs yielded values of path-loss exponent that vary between 2.00 and 3.25.
  - These measurements lead us to believe that for an airborne TA, the path-loss exponent is likely to be close to its free-space value of 2. (Higher received power levels at similar distances.)
  - The maximum observed throughput was 30 Mbps. In some instances, throughput levels between 25 and 30 Mbps were reached even at a distance of 16 km. Using this observation in conjunction with the previous one, one can reasonably expect an airborne TA to attain similar throughputs even at a distance of 20 km or so.
  - In the absence of interference, there should be a simple monotonic relationship between RSRP and throughput. In the field test, TCP and Iperf issues obscured this relationship. However, if one connects the mean throughput values at different RSRP levels, one can discern such a relationship. (The curve begins to flatten as it approaches 30 Mbps.)



Thank you



# REPORT DOCUMENTATION PAGE

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<b>14. ABSTRACT</b> In the Cellular Range Telemetry Network project, an initial field deployment and live operation has been conducted in Edwards AFB with LTE equipment tailored to accommodate aeronautical speeds. Ground tests and airborne tests have been carried out. We present an overview of the key elements of the field test setup and the test results that were collected. Particularly, we show the network architecture implemented, the radio components on the ground and in the test article, and the overall system configuration. Test data were collected with the test article installed on a ground vehicle at regular vehicular speeds. In addition, test data were collected from the operation of a Test Article in an airborne C-12. The behavior of the LTE network is shown via illustration of time series data, showing signal strength, data rates, handover operation and Doppler handling. The results presented showcase the current capability of the LTE technology in the test range environments.					
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