Distributed Beams: A Technique to Reduce the Scan Time of an Active Rotating **P**hased **A**rray **R**adar System

David Schvartzman

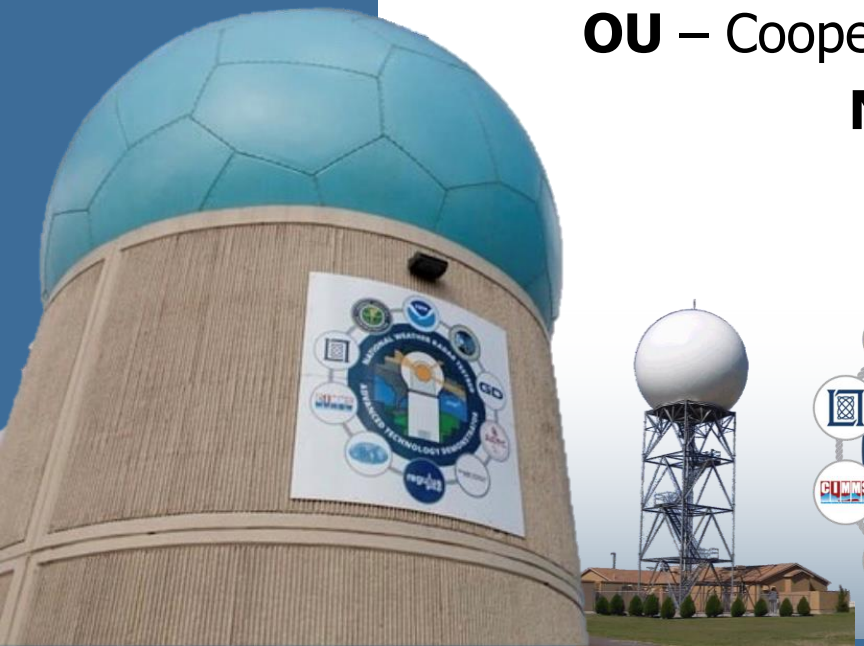
Sebastián Torres

OU – Cooperative Institute for Mesoscale Meteorological Studies (CIMMS)

NOAA - National Severe Storms Laboratory (NSSL)

Jan 15, 2020

Session 8B.2

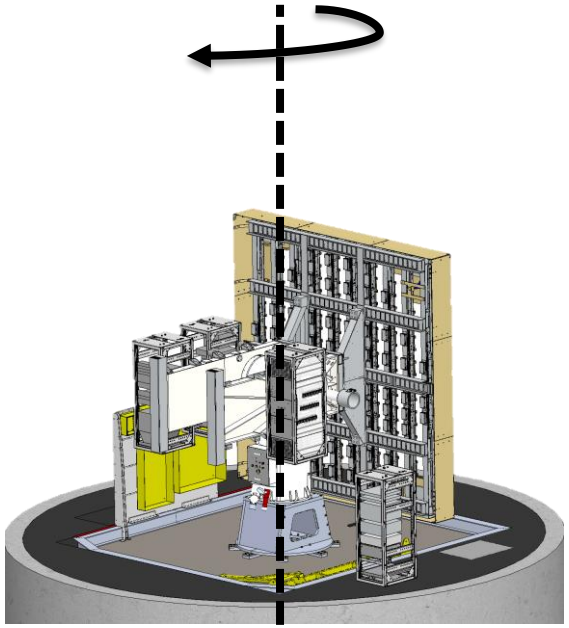


36th Conference on
Environmental Information Processing Technologies

AMS100
AMERICAN METEOROLOGICAL SOCIETY
100TH ANNUAL MEETING | BOSTON | 2020

Requirements for future US WSR

WSR-88D



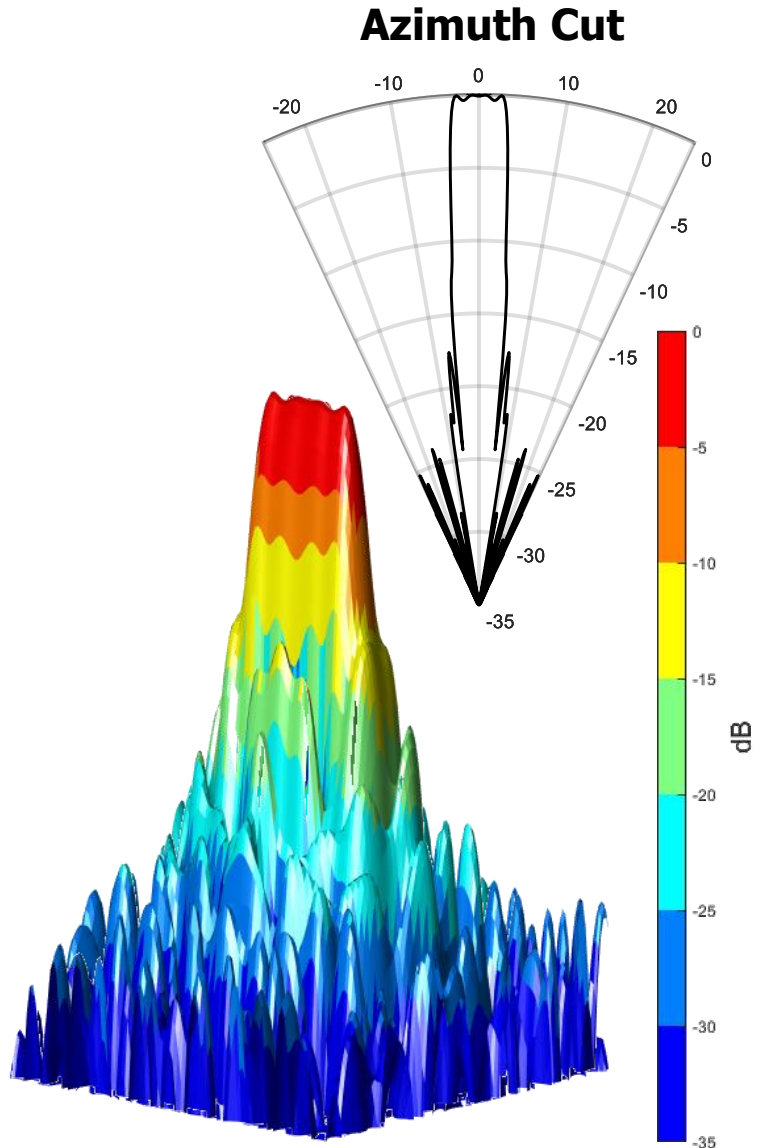
Rotating PAR (RPAR)

4-Faced static PAR

Can we **exploit PAR's unique capabilities** **enhanced** by the platform's **mechanical rotation** to achieve NWS requirements for Weather Surveillance?

PAR Unique Capability

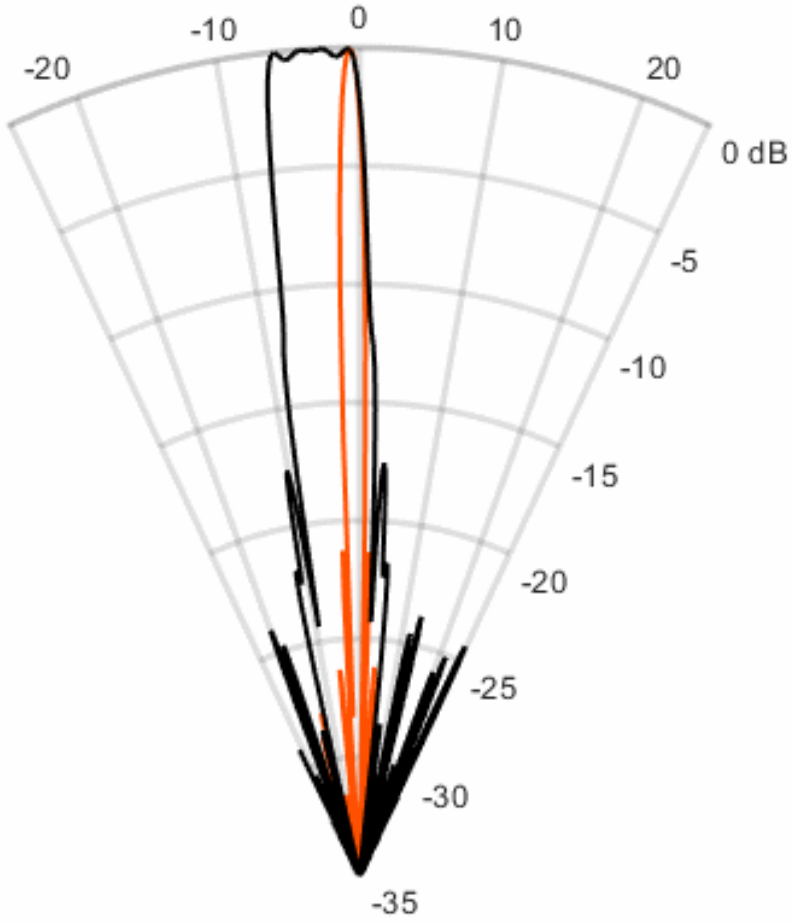
- Active PAR technology allows the **synthesis** of arbitrary **antenna beam patterns** on transmission.
- This capability can be used to produce a wider (**spoiled**) transmit beam, at the expense of reduced sensitivity.
- Depending on the PAR architecture, receive beams can be **simultaneously** formed digitally in certain directions.
- These digital receive beams use the full aperture to produce a narrow (**pencil**) beam.
- Transmission of spoiled beams is typically used in non-rotating PAR systems **to speed up the scan**.



Simulated Patterns

Exploiting PAR Beamforming

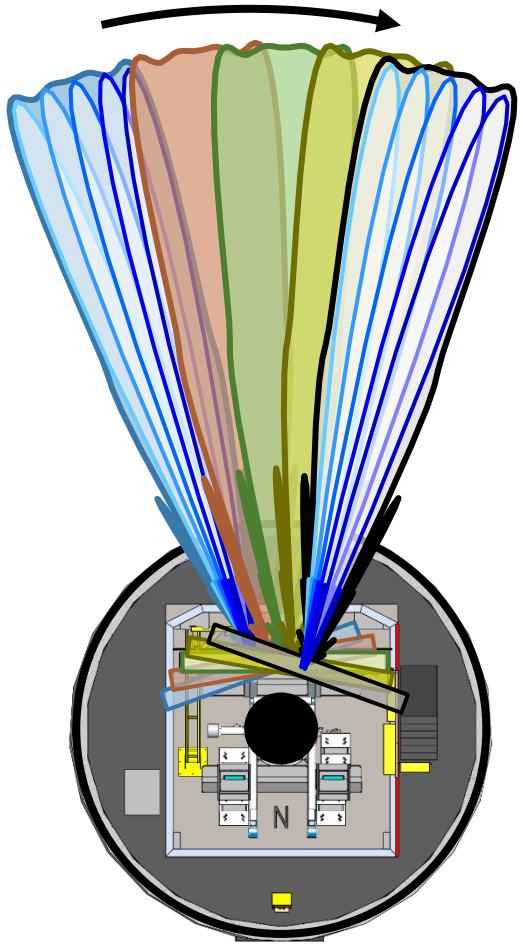
- Active PAR technology can be exploited by using beamforming capabilities in the context of a **rotating PAR Concept of Operations** (**ConOps**)
  - Transmit beam is spoiled by 5 in azimuth, and 5 **simultaneous** beams are received
- Absolute azimuth angles are **scanned by many digital receive beams** as the radar rotates and passes through each location
  - **Several receive beams** sampling the 0° azimuth angle as the radar rotates



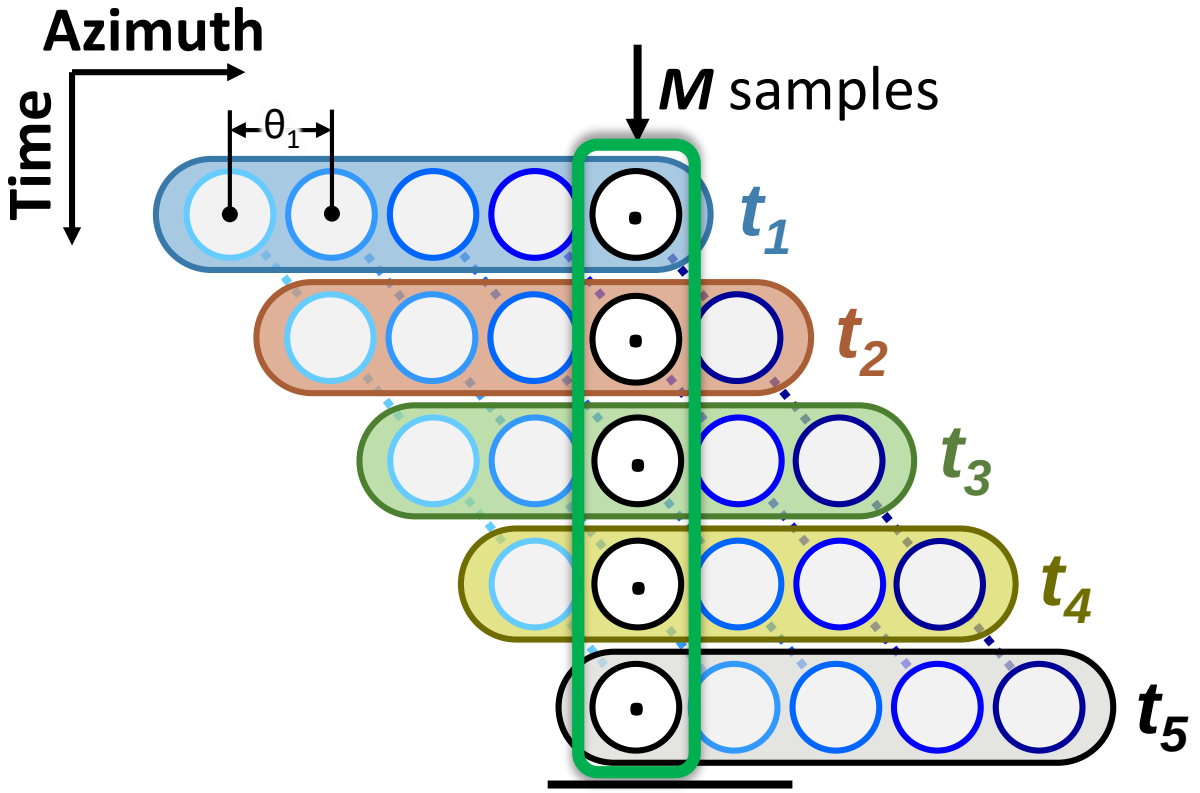
Rotating PAR

TX Beam Spoiled by 5

Distributed Beams (DB)

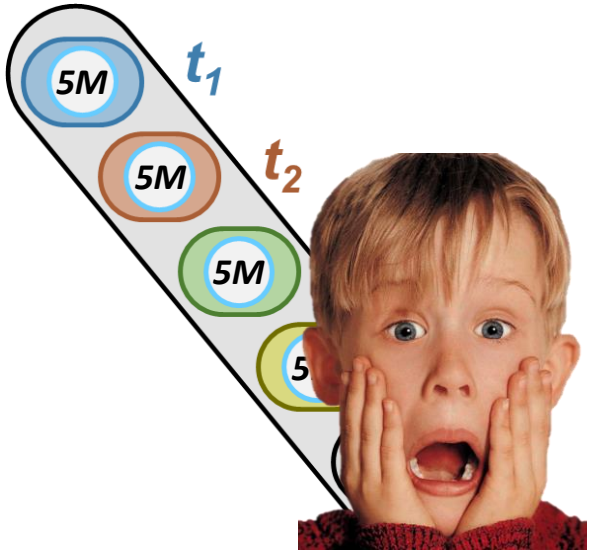


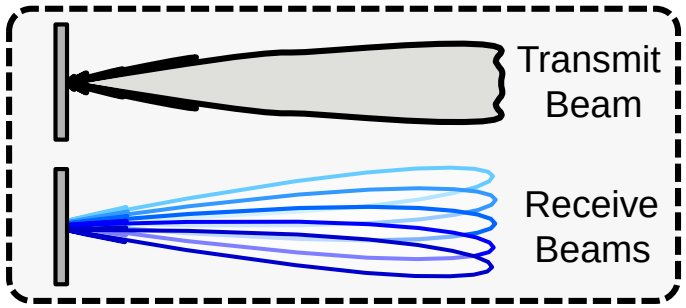
RPAR

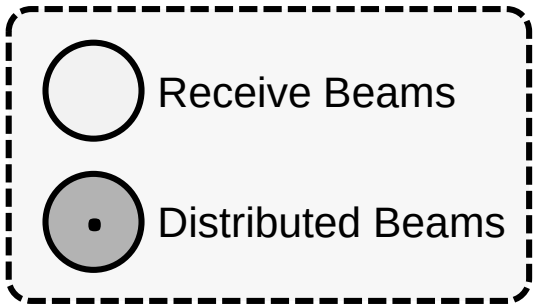


IN A Nutshell

If we used a pencil beam…





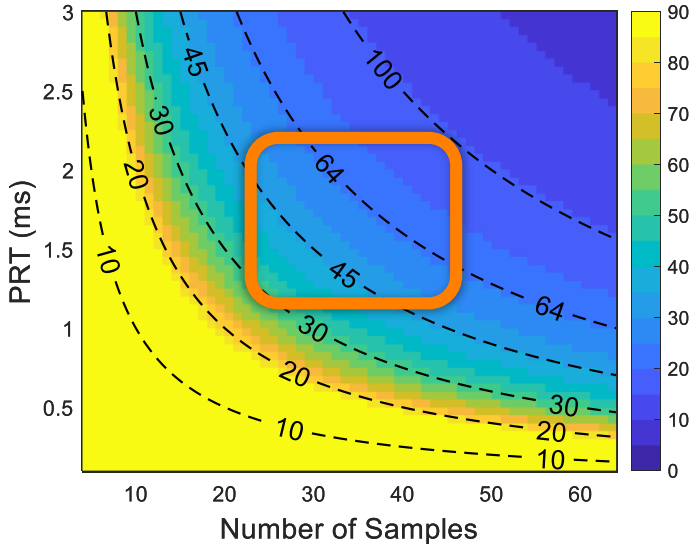


**More information can be found in the extended abstract.*

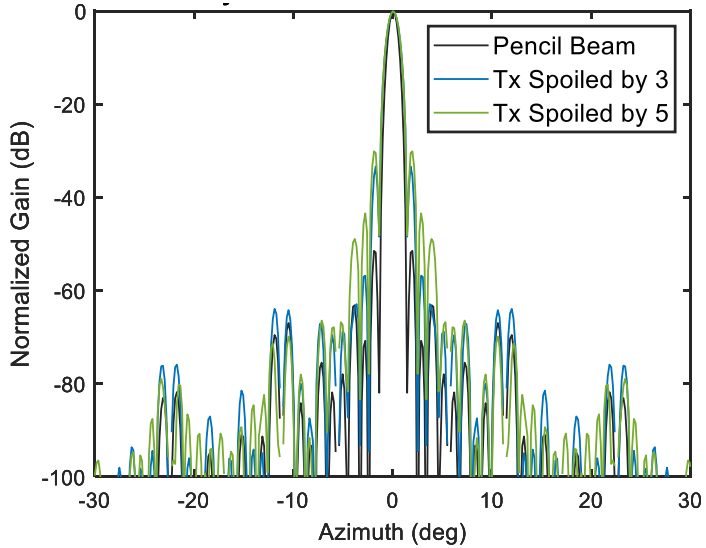
Limitations and challenges

- **Higher rotation speed**
  - Rotation speed has to be increased by the desired scan time reduction factor
- **Inherent limitations when spoiling the transmit beam**
  - Increased sidelobe levels, reduced sensitivity, slightly increased beamwidth
- **Mechanical pointing precision**
  - Errors in the mechanical pointing should be relatively small (~2% rotation speed)
- **Magnitude and phase calibration**
  - Transmit and receive patterns have to be measured

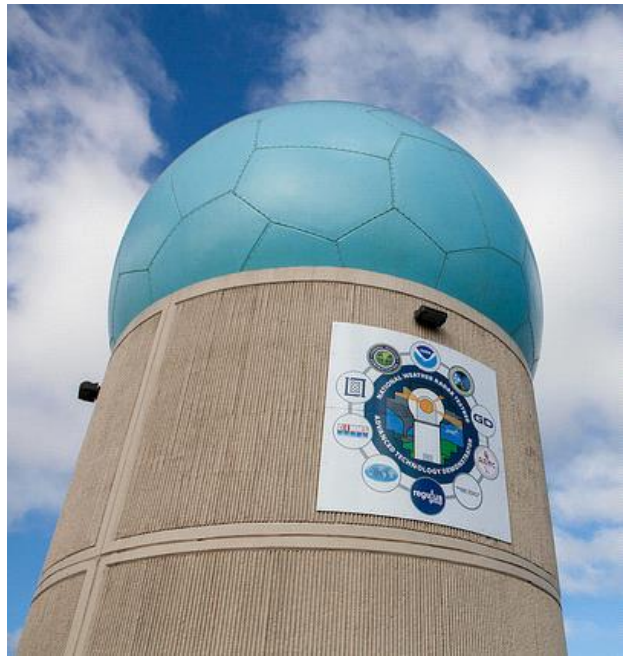
Rotation Speed (deg/s) – Spoiled by 3 + DB

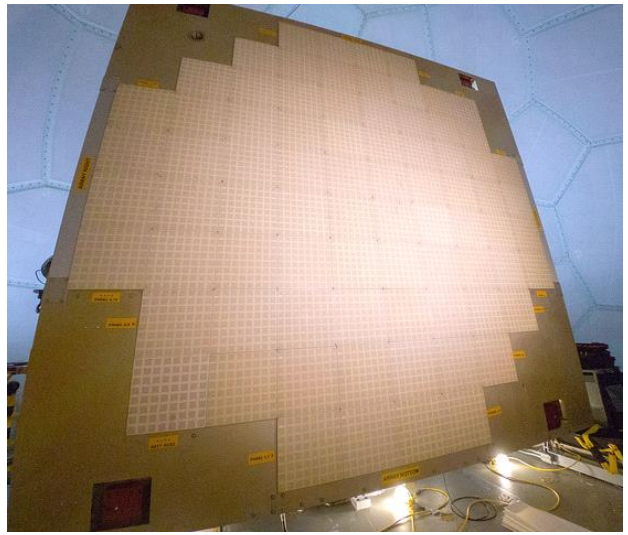


Two-Way Simulated Patterns



Advanced Technology Demonstrator (ATD)

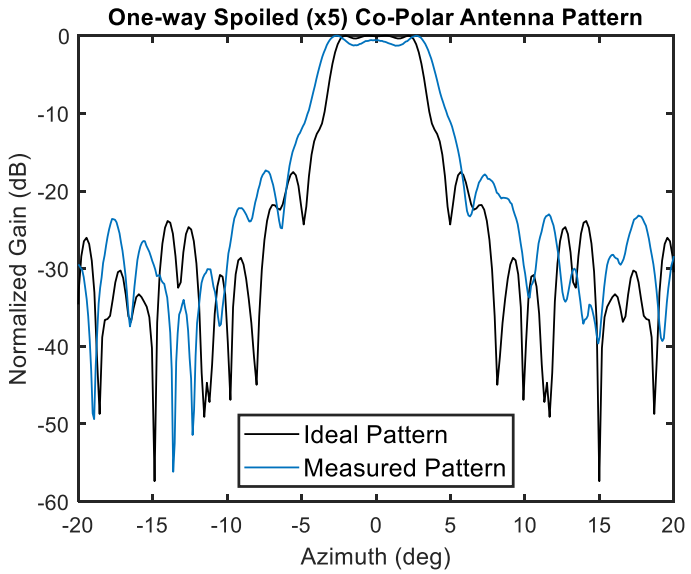




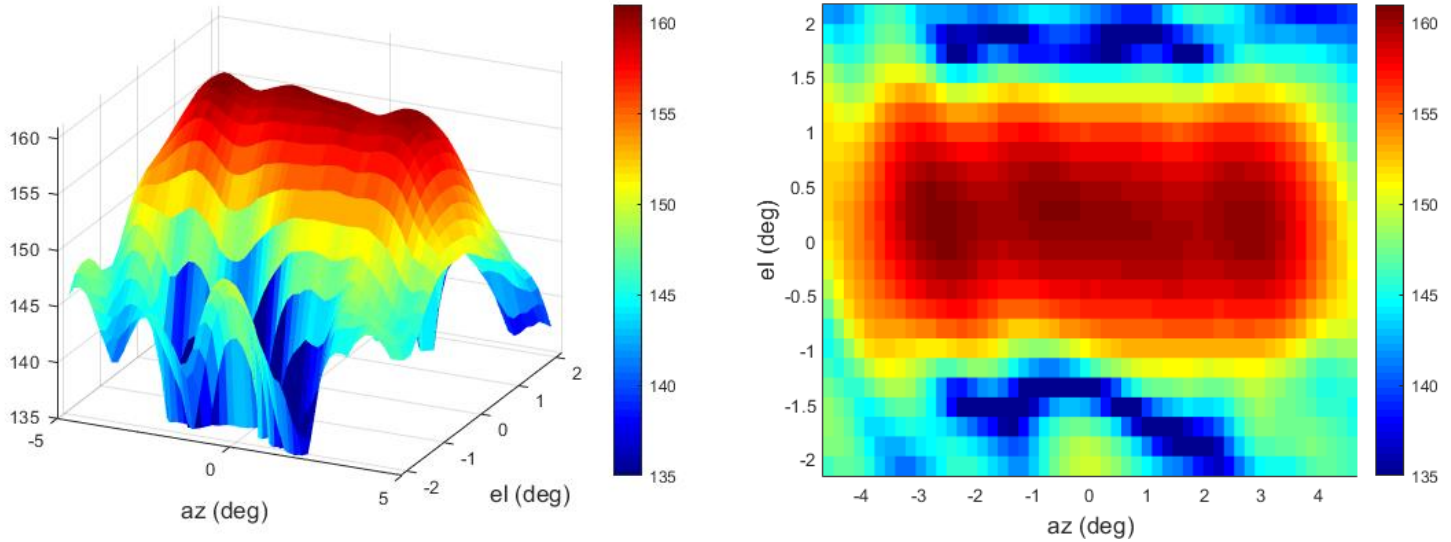
- The **ATD** is a **dual-polarization** S-Band, active, Phased Array Radar (**PAR**) installed in Norman, OK.
- It is funded through a collaboration of **NOAA** and the **FAA**; and being developed by NSSL, MIT-Lincoln Lab, General Dynamics, OU.
- Its main purpose is to evaluate the **suitability** of PAR technology for **weather observations**.
- The antenna is composed of 76 panels (8x8 elements each) for a total of **4864 elements** (**~1.6°** beamwidth at **broadside**).
- While the ATD was not designed for operating in a constant rotation regime, **it is capable of scanning while rotating**. This allows us to explore techniques in the context of a **RPAR ConOps**.

Demonstration using the ATD: Calibration

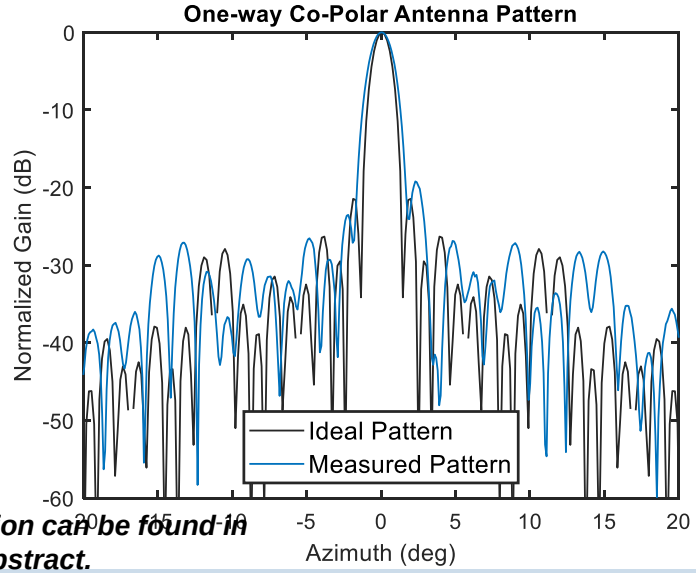
Transmit



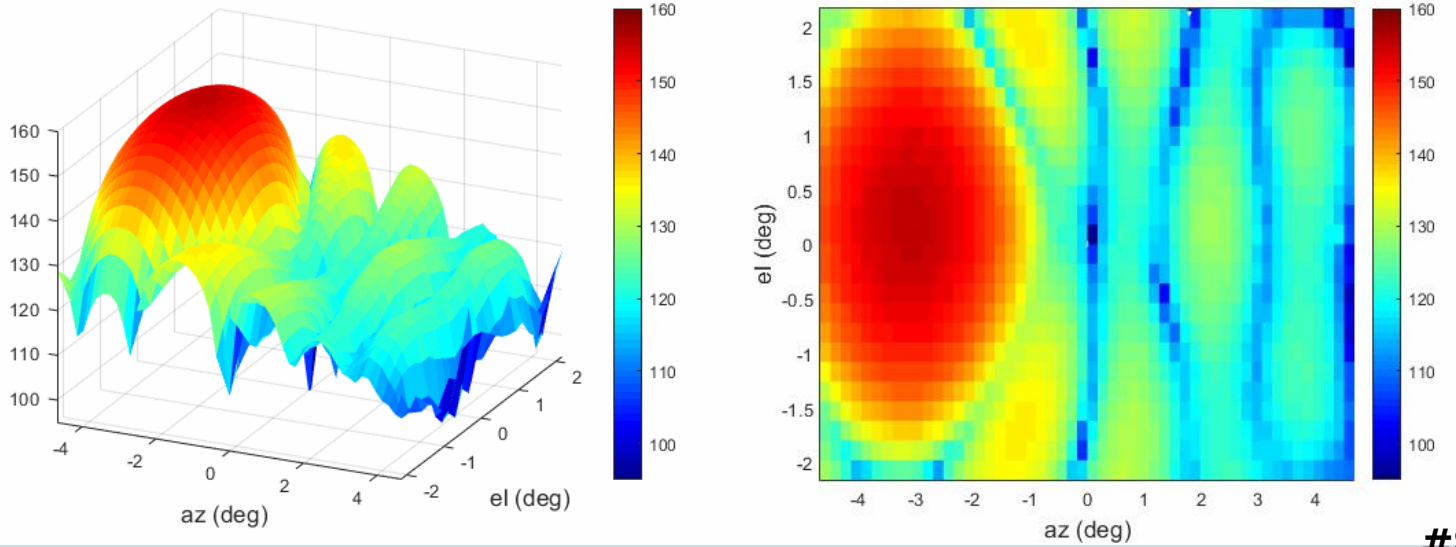
Measured Power (dB) for Spoiled Transmit Beam



Receive



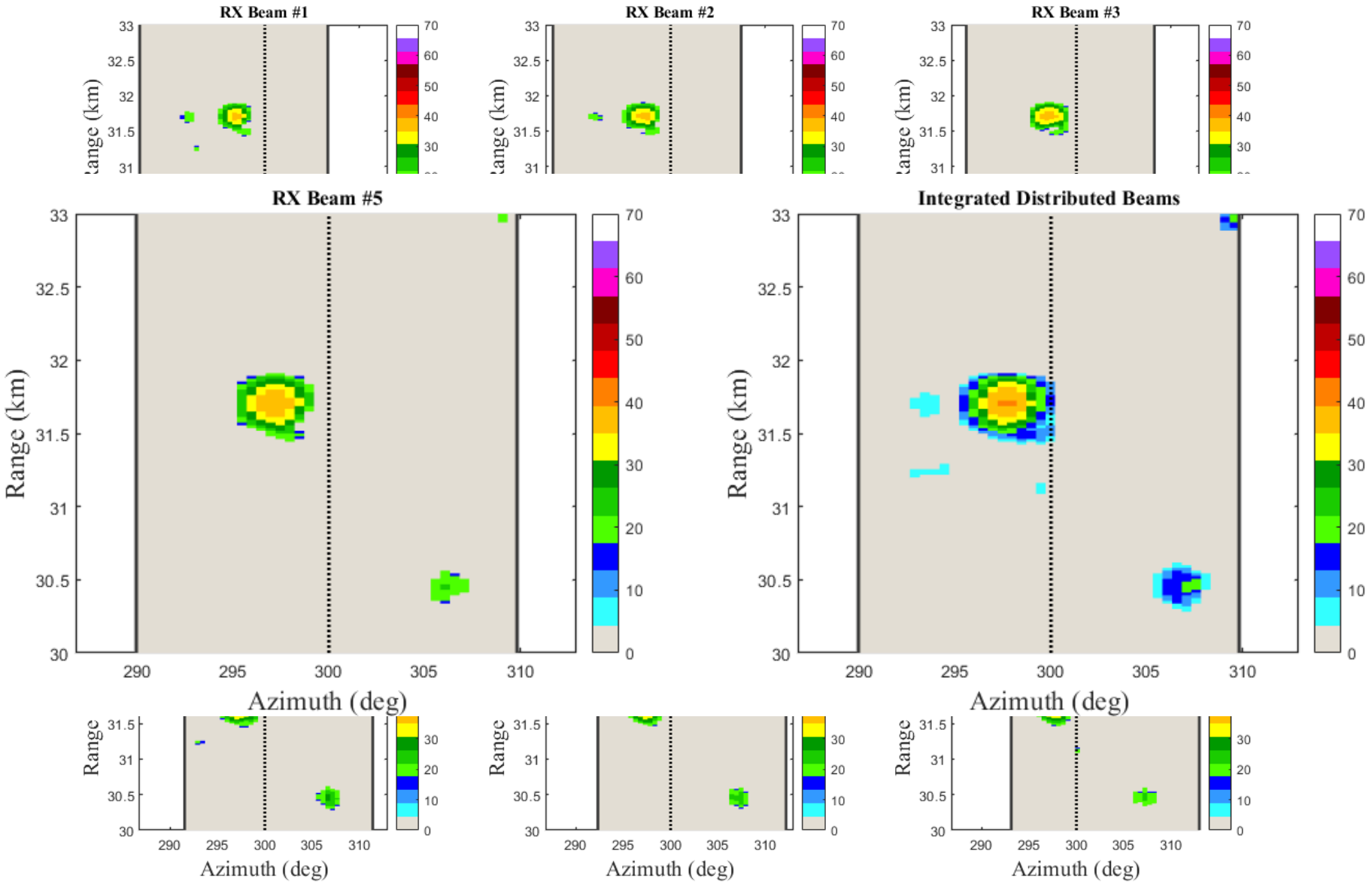
Measured Power (dB) for 9 Receive Beams



More information can be found in the extended abstract.

Demonstration using the ATD: Point Target

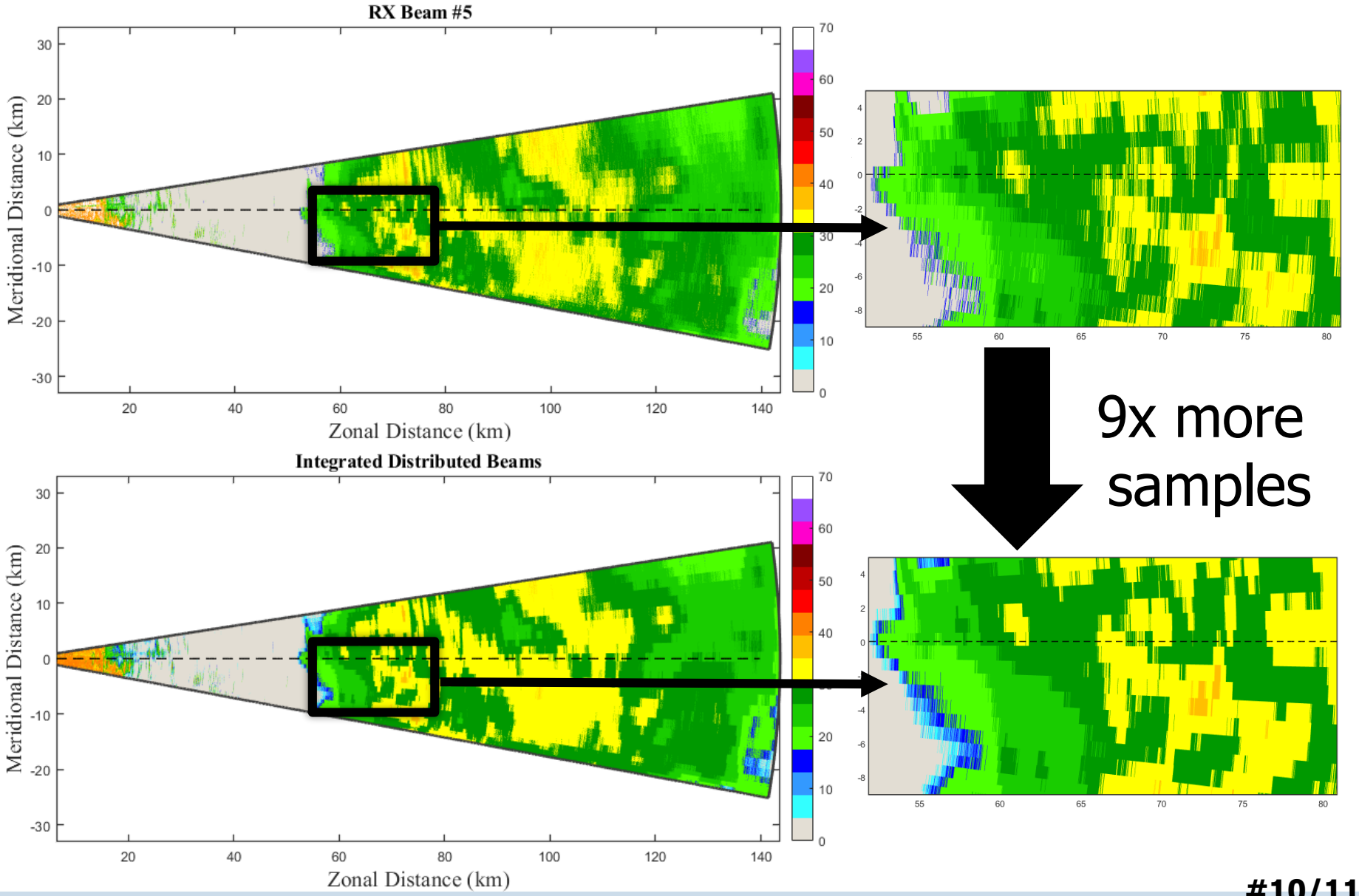
- **Scan setup**
  - PRT = 3 ms
  - Rotation Speed = 4.1 °/s
  - Az. Sampling = 0.79° (½ θ_1)
  - 64 pulses grouped per single receive beam dwell
  - Az. sector = (287.5°, 292.5°)
  - El. = 0.5°
- A total of 9 receive beams are produced simultaneously as the radar rotates
- Receive beams are spaced 0.79° (½ θ_1)



More information can be found in the extended abstract.

Demonstration using the ATD: Weather

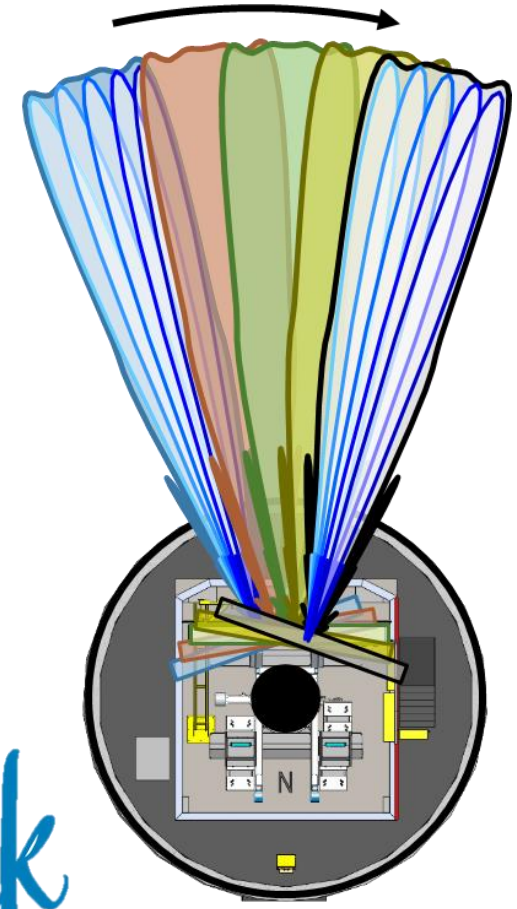
- **Scan setup**
  - PRT = 3 ms
  - Rotation Speed = 4.1 °/s
  - Az. Sampling = 0.79° (½ θ_1)
  - 64 pulses grouped per single receive beam dwell
  - Az. sector = (287.5°, 292.5°)
  - El. = 0.5°
- A total of 9 receive beams are produced **simultaneously** as the radar rotates
- Receive beams are spaced 0.79° (½ θ_1)



More information can be found in the extended abstract.

Summary

- We are exploring techniques to exploit **PARs unique capabilities** in the context of a **rotating concept of operations**
- The novel **Distributed Beams** technique could be **one of the tools** to achieve the required scan update times (~1 min)
- The preliminary results presented show that it can be used to **reduce the scan time**, or to improve the data quality (i.e., reduce the variance of estimates)



RPAR

thank you