Measured Channel Capacity and AoD Estimation for Multi-User MIMO Scenarios

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Introduction

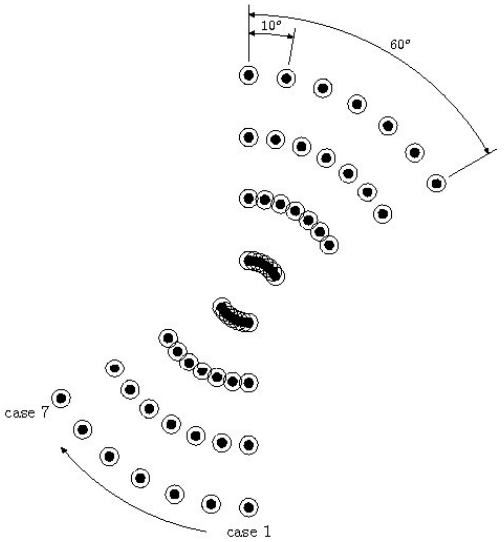
- During the TGac channel model addendum document discussion in Vancouver meeting, there was interest in studying the AoD spectrum variation as a function of client location and orientation.

- This presentation describes measurement results performed at ETRI to address the following issues:
  - Sensitivity of SDMA channel capacity to Transmit and Receive antenna orientation.
  - Variation of SDMA DL AoD spectrum as a function of client location.

Measurement Scenario

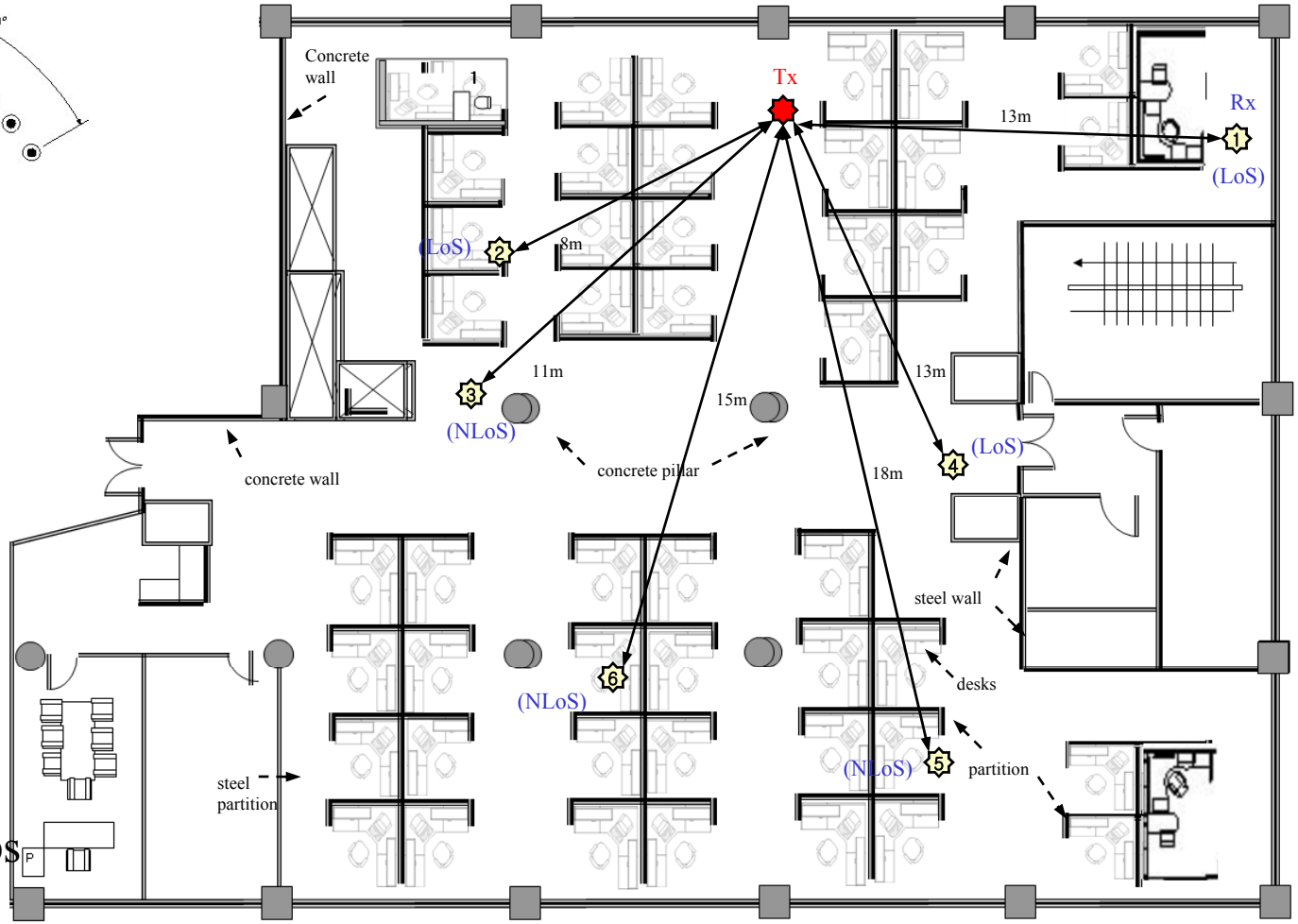
- 1 Tx AP (8 antennas) and 6 Rx STAs (2 antennas each)
- Antenna Configurations
  - Uniform Linear Antenna: 8x2
  - Tx Ant Orientation: $-30^{o} \sim +30^{o}$ in 10^{o} steps
  - Rx Ant Orientation: $-180^{o} \sim +180^{o}$ in 30^{o} steps
- Measurement Site
  - Office environment
  - 1st floor, bldg. #7, ETRI
  - 3 LOS, 3 NLOS

Floor Map of the Measurement Site



Tx ant orientation:
-30°~30° in 10° steps

Rx ant orientation:
-180°~180° in 30° steps



The Measurement Site

Tx Ant System

Tx antenna height = 2m

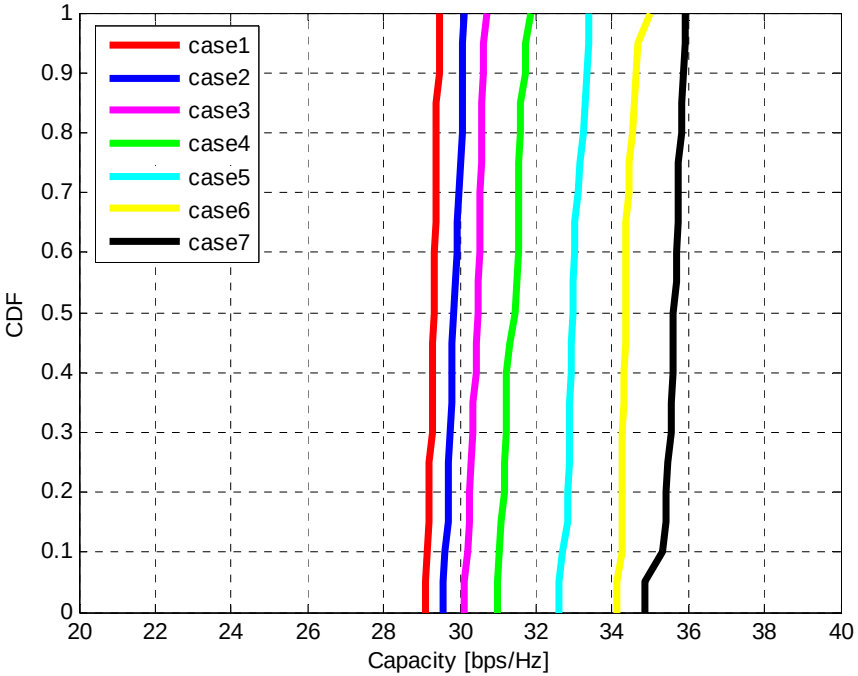
Rx antenna height = 90cm

LOS

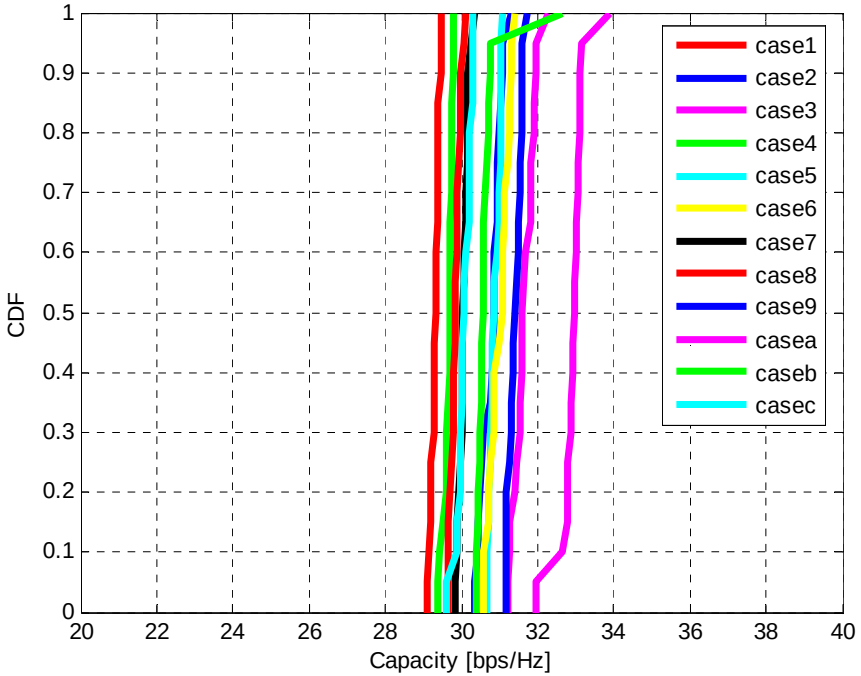
Non-LOS

Sensitivity to Antenna Orientation (NLOS)

- Capacity is calculated by using MMSE post-SINR
- 4 STAs: STA #3 (NLOS), #4 (LOS), #5 (NLOS), #6 (NLOS)
  - Tx ant orientation: -30° ~ +30° in 10° steps (case1 ~ case7)
  - Rx ant orientation: -180° ~ +180° in 30° steps (case1 ~ caseC)



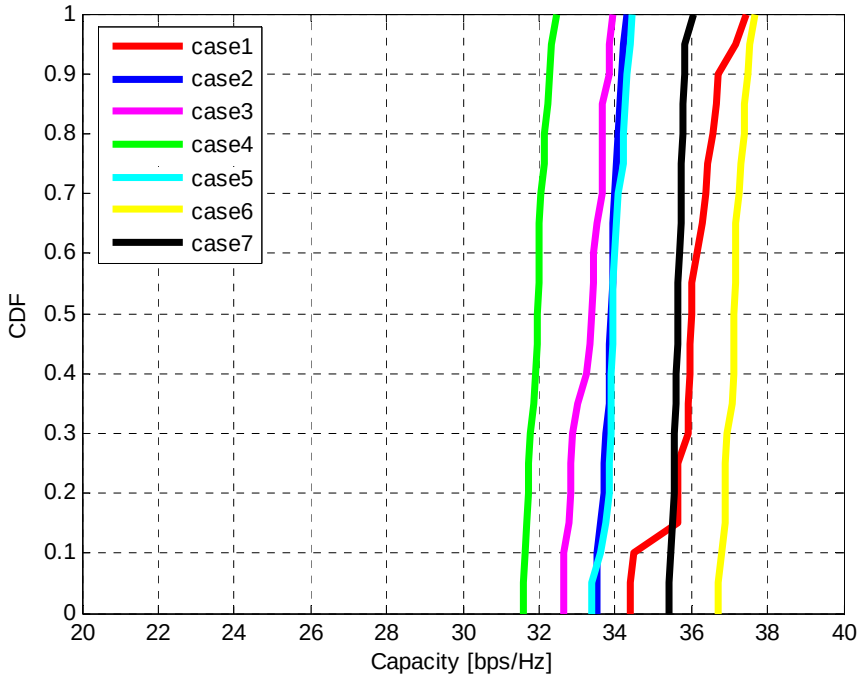
Tx ant orientation: -30° ~ +30°
Rx fixed at case 1



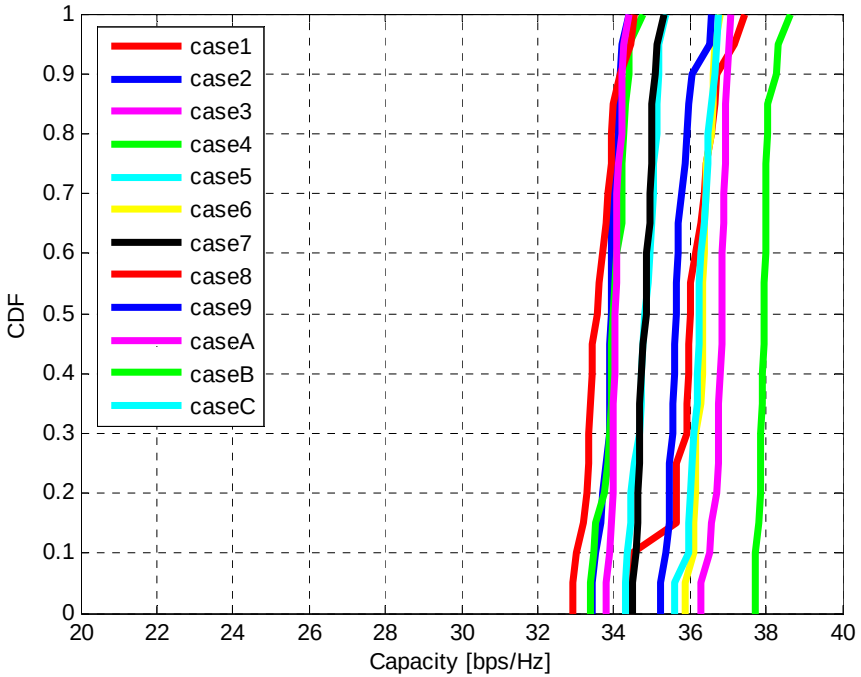
Rx ant orientation: -180° ~ 180°
Rx fixed at case 1

Sensitivity to Antenna Orientation (LOS)

- Capacity is calculated by using MMSE post-SINR
- 4 STAs: STA #1 (LOS), #2 (LOS), #3 (NLOS), #4 (LOS)
  - Tx ant orientation: -30° ~ +30° in 10° steps (case1 ~ case7)
  - Rx ant orientation: -180° ~ +180° in 30° steps (case1 ~ caseC)



Tx ant orientation: -30° ~ +30°
Rx fixed at case 1



Rx ant orientation: -180° ~ 180°
Tx fixed at case 1

Sensitivity to Antenna Orientation: Conclusions

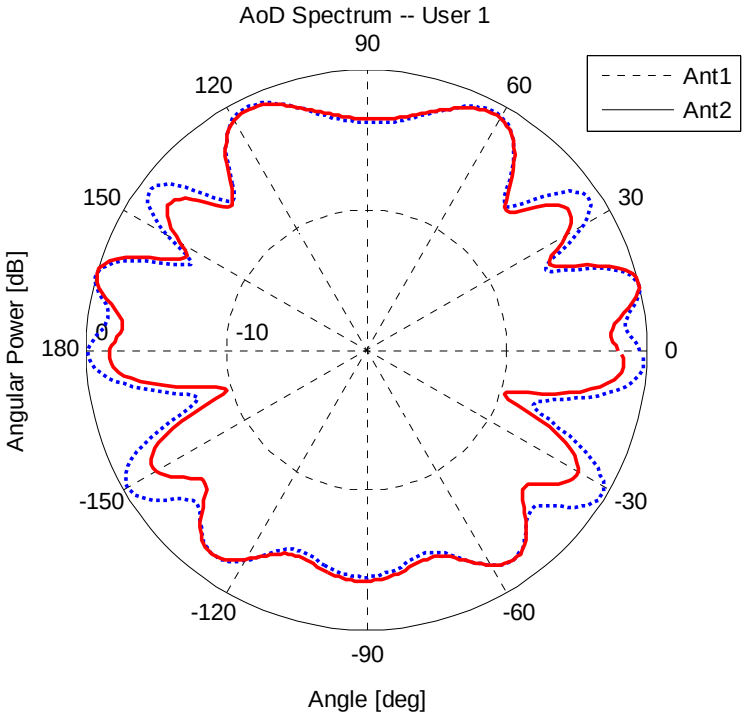
- SDMA channel capacity is sensitive to the Tx and Rx antenna orientations
- Capacity is more sensitive to the orientation of the Tx antenna array than that of the individual Rx client arrays. For example,
  - NLOS:
    - 32 ±3 bps/Hz when Tx ant. orientation changed ($\Delta\theta = 60^o$)
    - 31 ±2 bps/Hz when Rx ant. orientation changed ($\Delta\theta = 360^o$)
  - Note: The absolute values of the capacities are not relevant. We should be focused on the trend/pattern, etc
- The above result indicates that TGac MU-MIMO channel models need to incorporate AoD variation across clients, to be realistic.

AoD Estimation from Linear Array Measurements

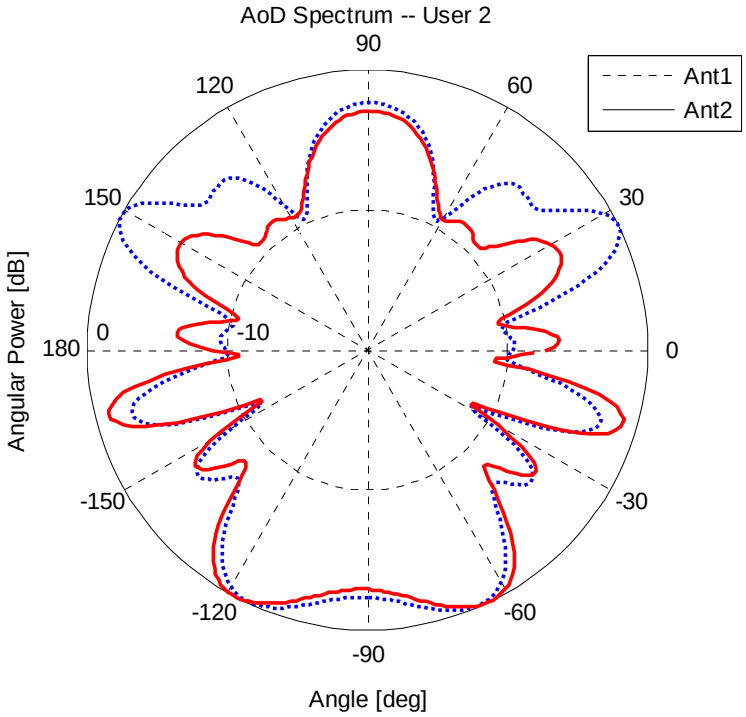
- **The AoD spectrum is estimated from linear array measurements by the following method:**
  - Assume:
    - Antenna array length = N
    - Antenna separation (relative to wavelength) = (d/λ)
      - Phase vector $A(\theta) = [1 \quad e^{j2\pi(d/\lambda)\sin\theta} \quad e^{j4\pi(d/\lambda)\sin\theta} \quad \ldots\ldots \quad e^{j(N-1)2\pi(d/\lambda)\sin\theta}]$ where θ = AoD
    - Received channel vector for the j-th time-domain tap = h_j
- **The AoD spectrum is obtained by plotting $20\log_{10}(\| h_j A(\theta) \|)$ vs. θ.**
- **For the purposes of this presentation, the AoD has been averaged across all time-domain taps.**

AoD Spectrum at Each STA (1/3)

- Tx antenna orientation: case 7
- Rx antenna orientation: case 1



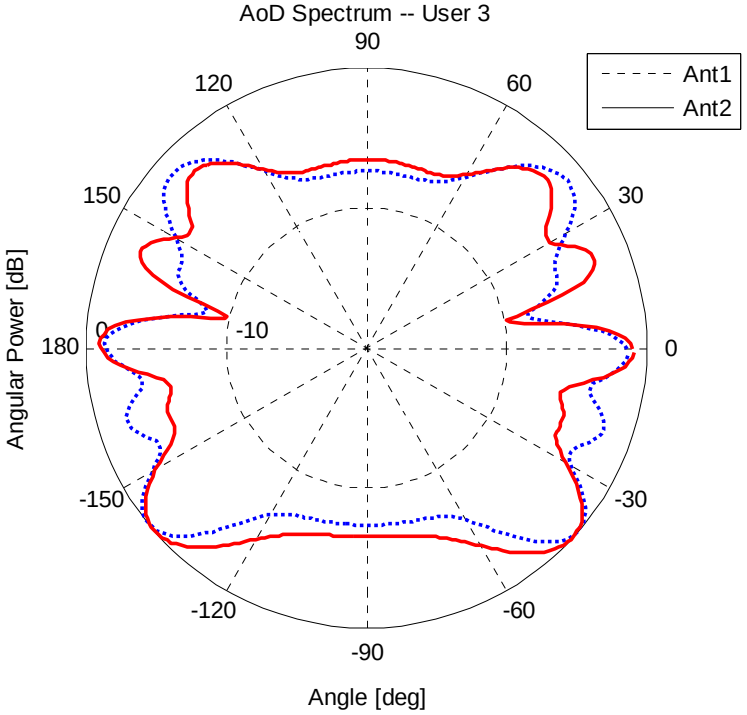
User 1



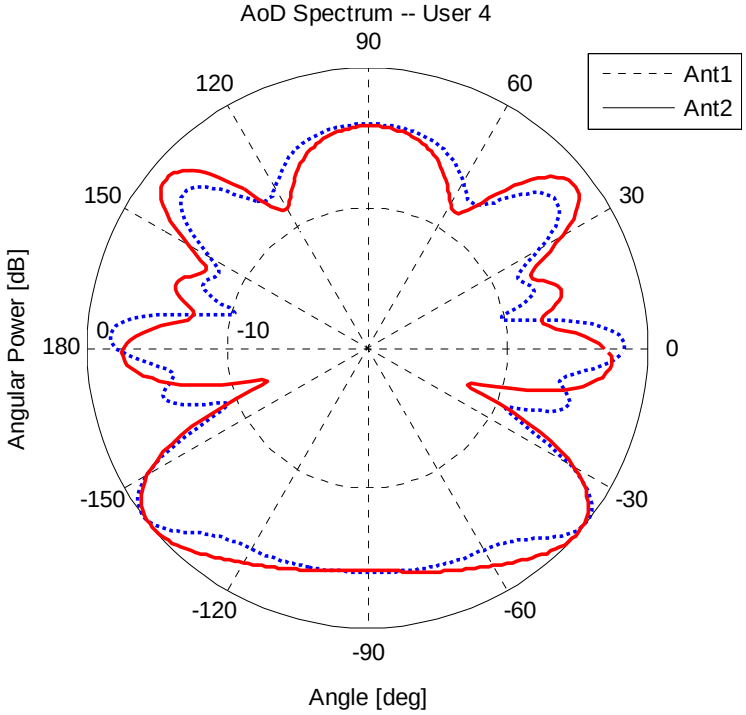
User 2

AoD Spectrum at Each STA (2/3)

- Tx antenna orientation: case 7
- Rx antenna orientation: case 1



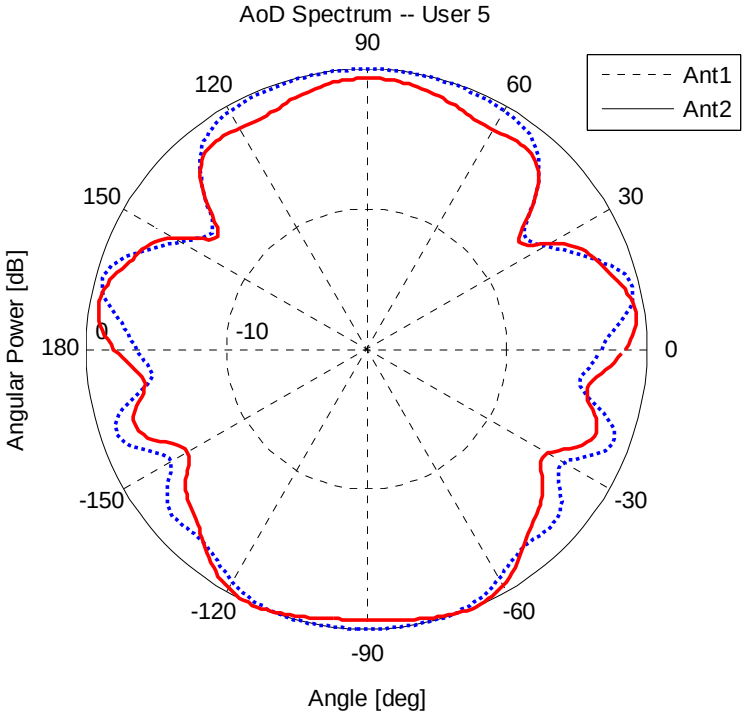
User 3



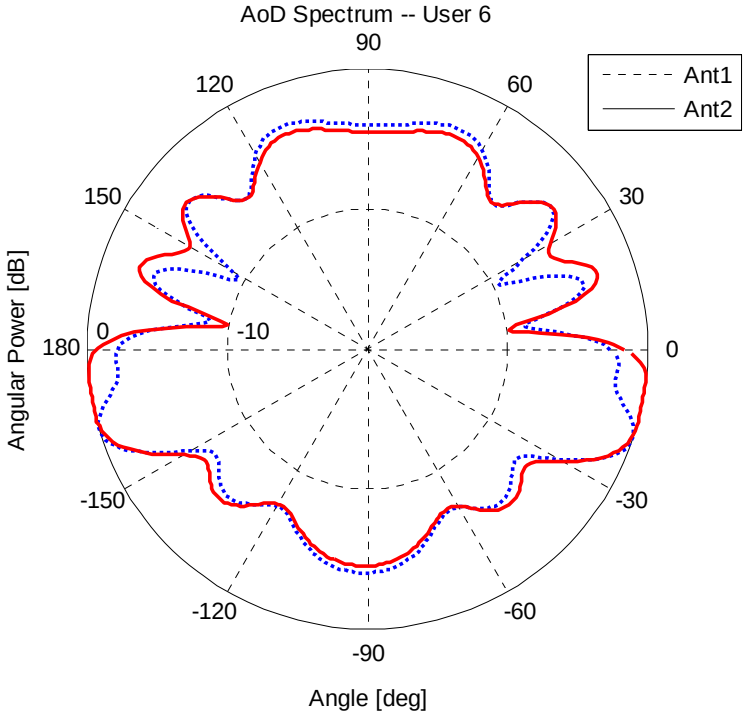
User 4

AoD Spectrum at Each STA (3/3)

- Tx antenna orientation: case 7
- Rx antenna orientation: case 1



User 5



User 6

Variation of AoD spectrum: Conclusions

- Measurements suggest considerable AoD variation across clients.
  - Note: AoD range of approx $\pm 30^{o}$ was suggested for NLOS clusters in the TGac channel model addendum document.
- Further analysis and measurements are underway to characterise AoD variation, on a cluster-by-cluster basis.
- We recommend that the TGac channel model addendum document use a "TBD" value for AoD range, until the analysis is completed.