MIMO in 6G: statistical channel model and capacity prediction for ELAA-mMIMO

Yi Ma *

5G Innovation Centre (5GIC) and 6G Innovation Centre (6GIC)

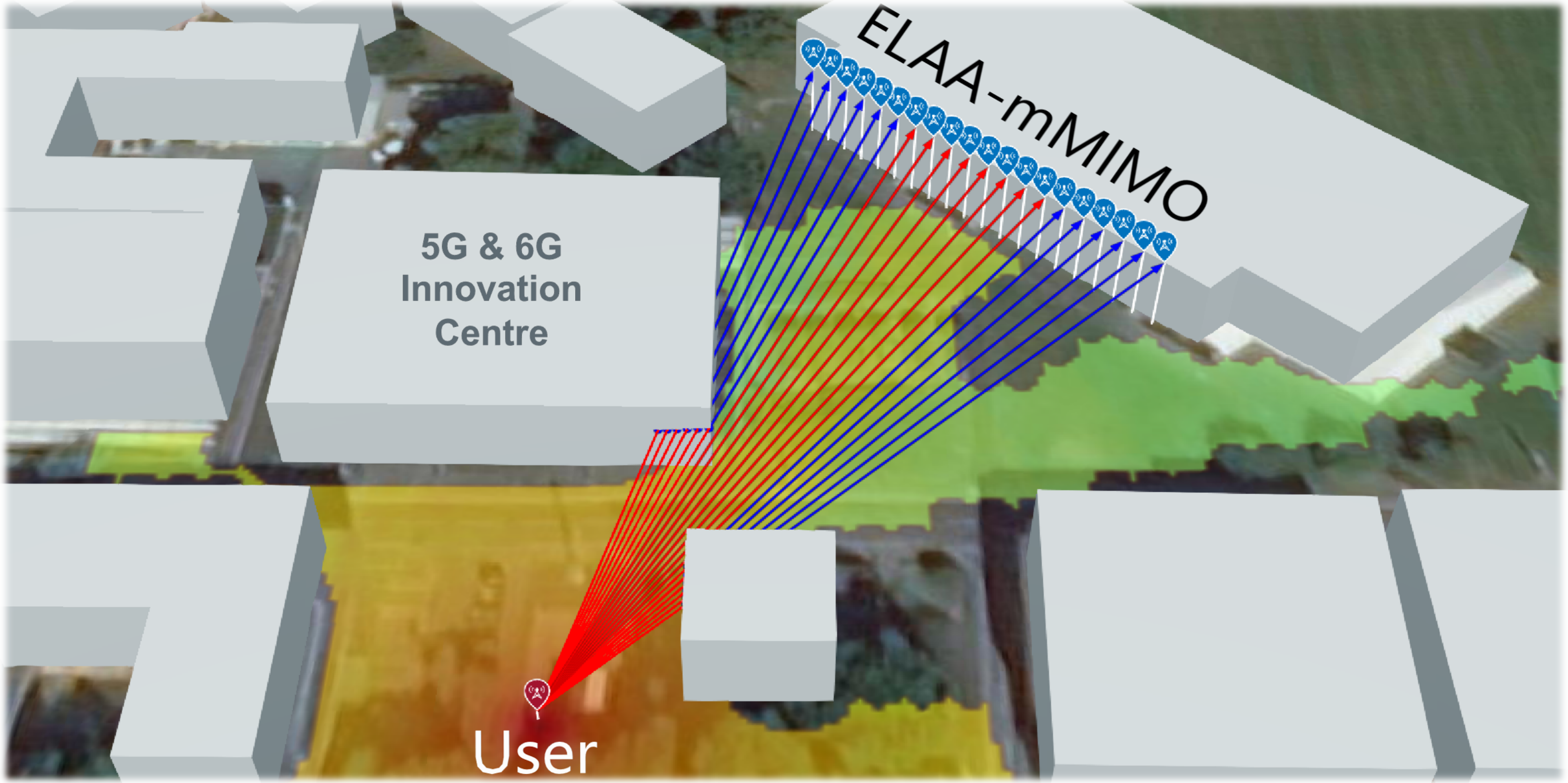
Institute for Communications (ICS), University of Surrey

DCMS 6G Workshop

* This work presents the contribution from our group members: Jiuyu Liu, Jinfei Wang, and Na Yi.

Extra-Large Aperture Array massive-MIMO

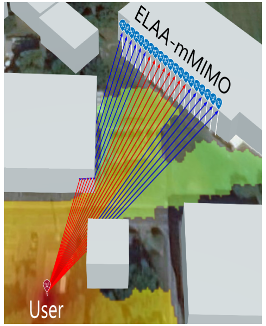
An example from the University of Surrey, Stag Hill Campus

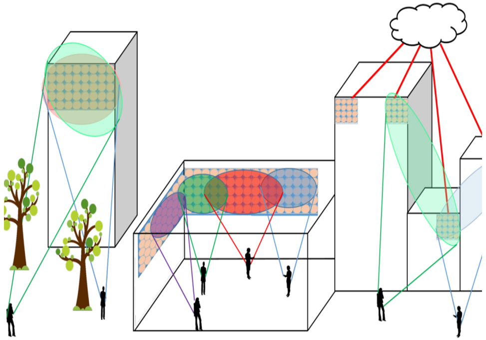


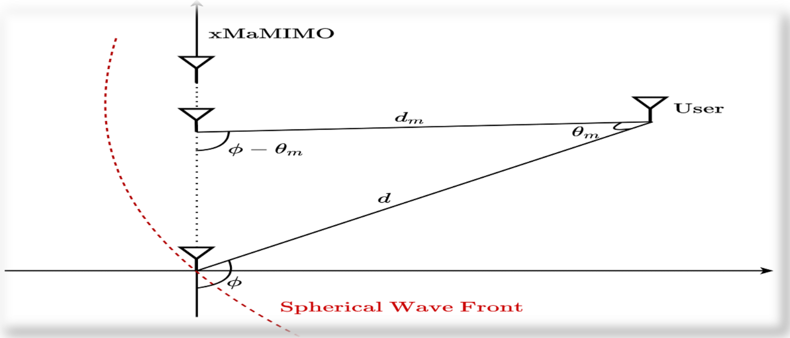
ELAA-mMIMO can be 4N-MIMO

- Channel spatial nonstationarity: user-to-service antenna links can have different channel statistics.
- Nonlinearity: low-resolution ADC/DAC, power amplifier, mixer, etc.
- Non-Gaussianity: low-resolution ADC/DAC, etc.
- Non-Ergodicity: short packet transmissions.

ELAA-mMIMO Channel Modeling



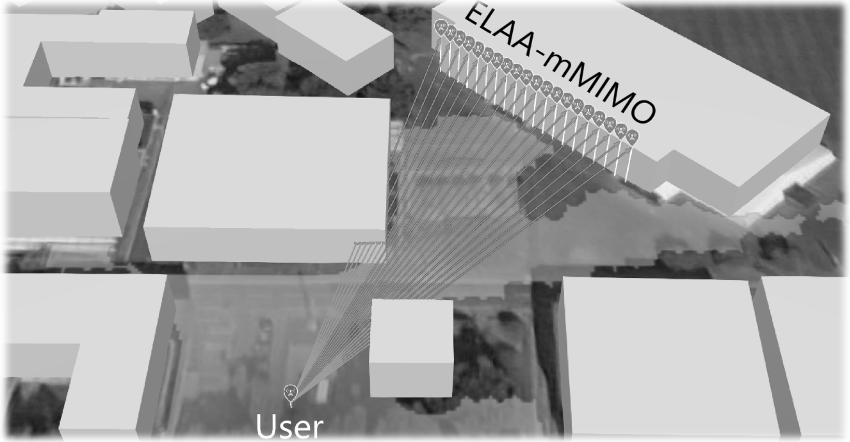


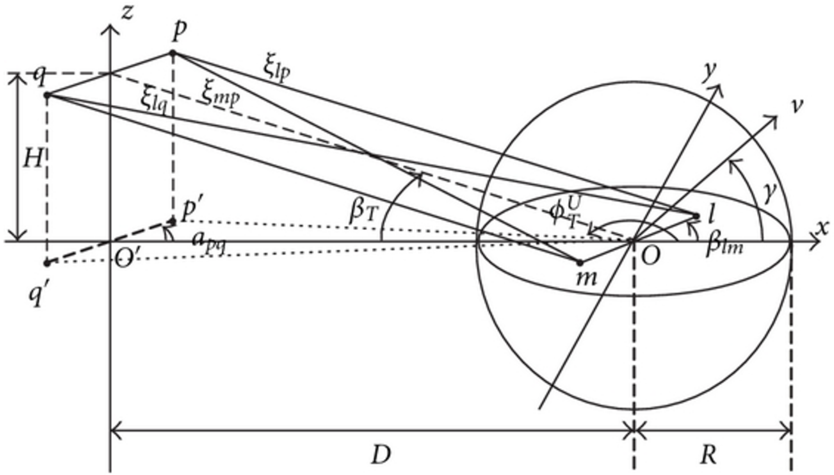


How to model the channel spatial non-stationarity?

- ❖ Near-field region (no longer a far-field model)
- ❖ Spherical wavefront (no longer a plane wavefront)
- ❖ Non-identical and non-independent probability distribution
- ❖ A sparse graph (partially connected MIMO)
- ❖ A mix of LOS/NLOS links

Need for Statistical Channel Models



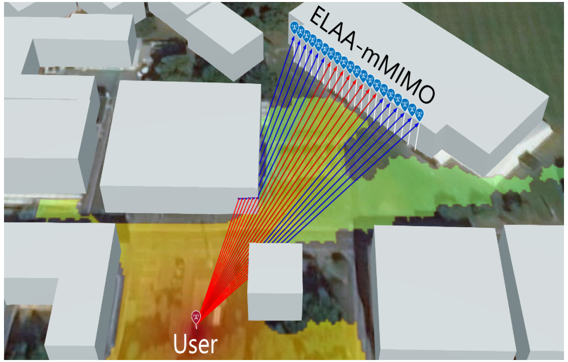


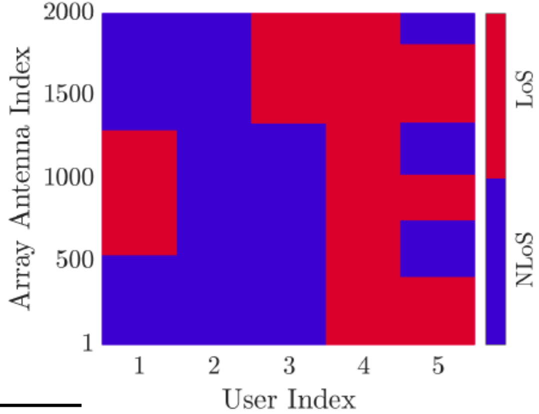
- ❖ Map-based deterministic channel models
- ❖ Geometry-based stochastic channel models

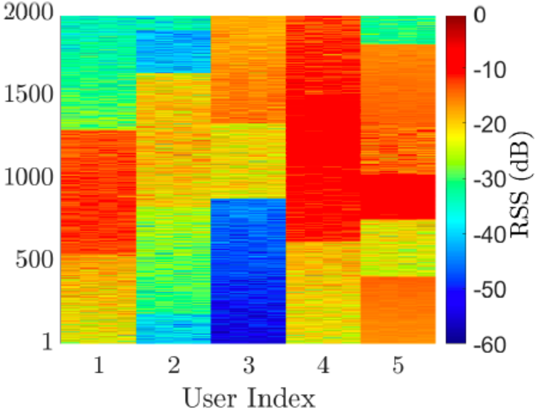
Not suitable for link-level ELAA-mMIMO simulations.

- ❖ **A simple and trackable statistical channel model is needed for link-level study.**

A Novel Statistical Channel Model







Algorithm Random Realization of $\mathbf{h}$

Input:

M: the number of service antennas;
d_ℓ^{2D}: the 2-D distance used in (7);
$\lambda, d_{\mathrm{cor}}$: parameters used in (10);

Output:

$\mathbf{h}$: the channel vector;

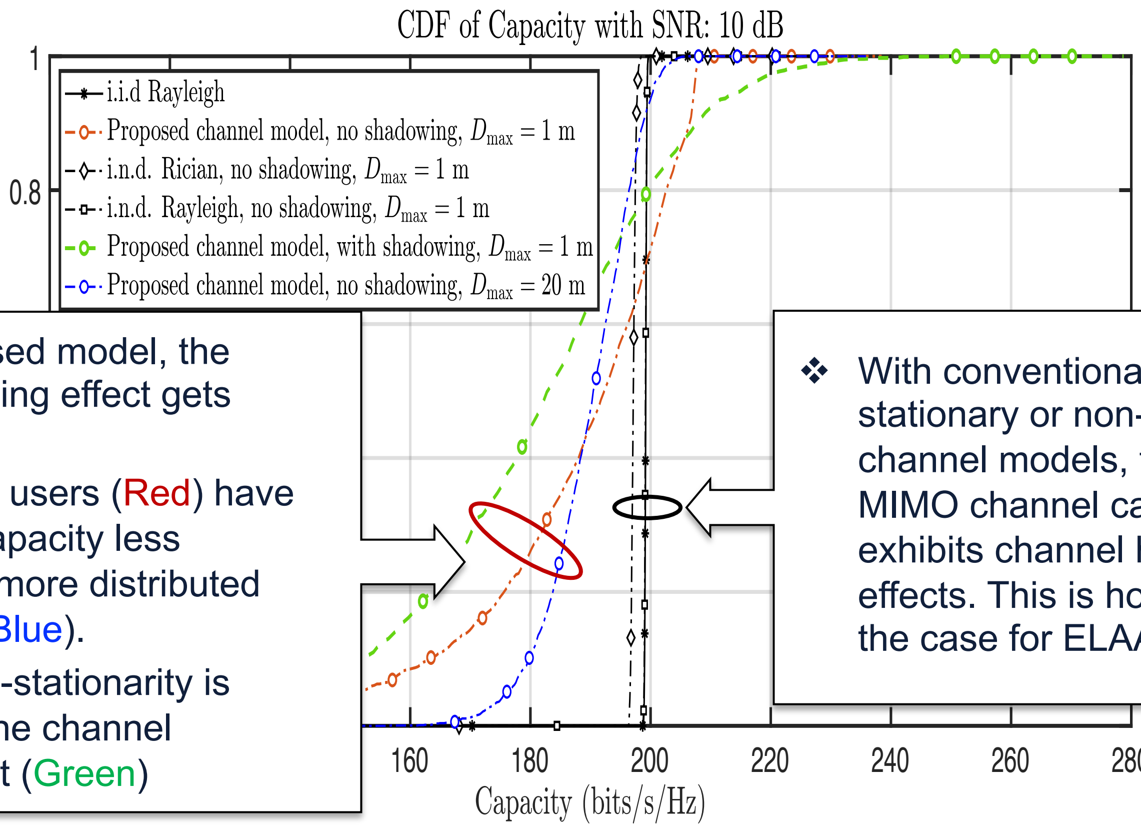
START

1: **let** $\ell = 0$; call (7) to compute $\mathcal{P}_{\mathrm{LOS}}(d_\ell^{\mathrm{2D}})$;
2: **let** $p = \mathcal{P}_{\mathrm{LOS}}(d_\ell^{\mathrm{2D}})$ and generate b_ℓ according to the Bernoulli distribution in (5); **let** $m = \ell + 1$;
3: Generate b_m according to the distribution in (10);
4: **if** $b_m = b_\ell$, **then** $m \leftarrow m + 1$; **otherwise** $\ell \leftarrow m$, **goto** step 2;
5: **repeat** step 3 until $m = M$;
6: Generate $\mathbf{h}$ using (4) and conduct the normalization;

END

- The proposed statistical channel model is simple and trackable.
- It captures spatial consistencies for LoS/NLoS, shadowing effects, and fading behaviours.
- Flexible to environment changes.
- Easy to implement for link-level Monte Carlo simulations.
- Following 3GPP channel measurement results.

Capacity Prediction Using Statistical Channel Models

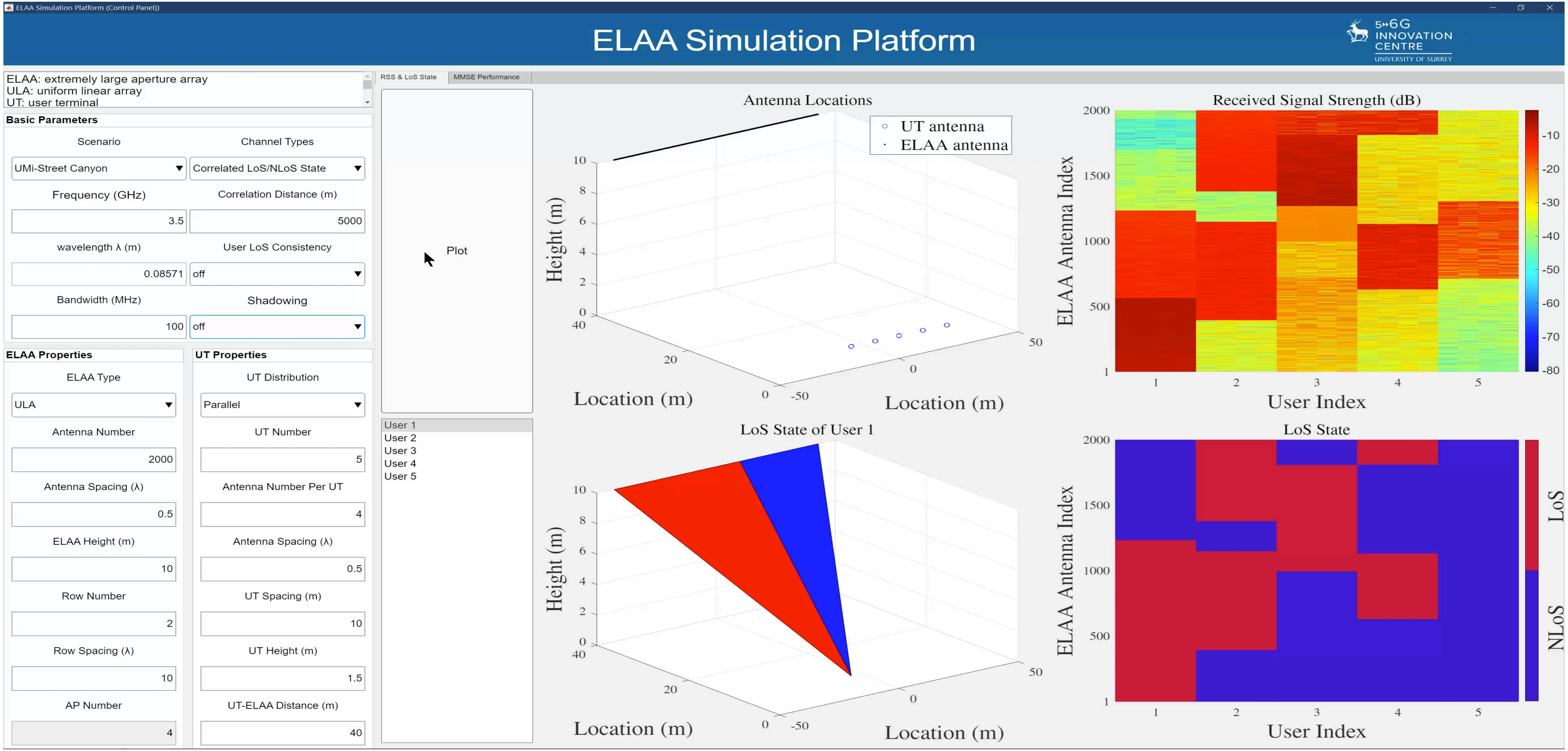


- With the proposed model, the channel hardening effect gets weaker.
- Closely-located users (Red) have their channel capacity less hardened than more distributed located users (Blue).
- Shadowing non-stationarity is detrimental to the channel hardening effect (Green)

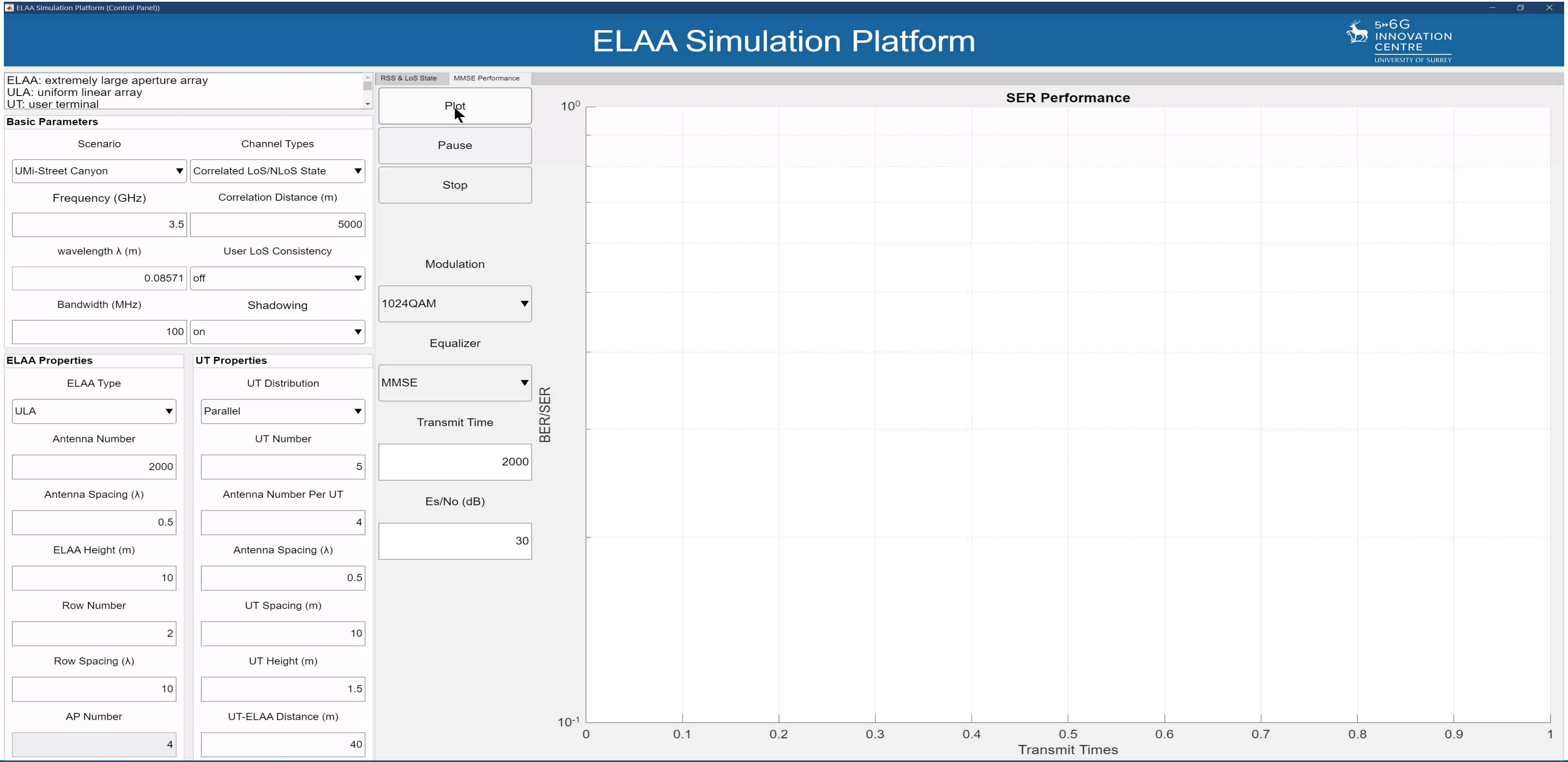
- With conventional mMIMO stationary or non-stationary channel models, the ELAA-MIMO channel capacity exhibits channel hardening effects. This is however not the case for ELAA-MIMO.

Integration of Channel Models in Simulation Platform (1/2)

5»6G INNOVATION CENTRE
UNIVERSITY OF SURREY



Integration of Channel Models in Simulation Platform (2/2)



Conclusion and Outlook

- We are working towards a fundamental paradigm shift in the MIMO research – 4N Wireless MIMO.
- Established the foundation for the future mMIMO research with a novel contribution on statistical nonstationary MIMO channel model – **Simple**, **Trackable**, **Accurate**, and suitable for link-level study.
- Capacity prediction based on conventional and novel nonstationary MIMO channel models – **found the impact of nonstationarity on mMIMO channel capacity (spectral effieicny) and channel hardening effects**.
- Demonstrated link-level simulations using the developed channel models.
- Extend the channel model to more complicated multiuser scenarios.

References & Related Reading

[1] J. Liu, Y. Ma, et al, "A novel stochastic spatially non-stationary channel model and capacity analysis for ELAA," **IEEE Globecom** 2021(submitted).

[2] J. Liu, Y. Ma, et al, "Statistical channel models and capacity prediction for ELAA-mMIMO concerning network-user two sides LoS consistency," **IEEE Trans. Wireless Commun**., 2021 (Under Preparation)

Thank You

Yi Ma
y.ma@surrey.ac.uk