

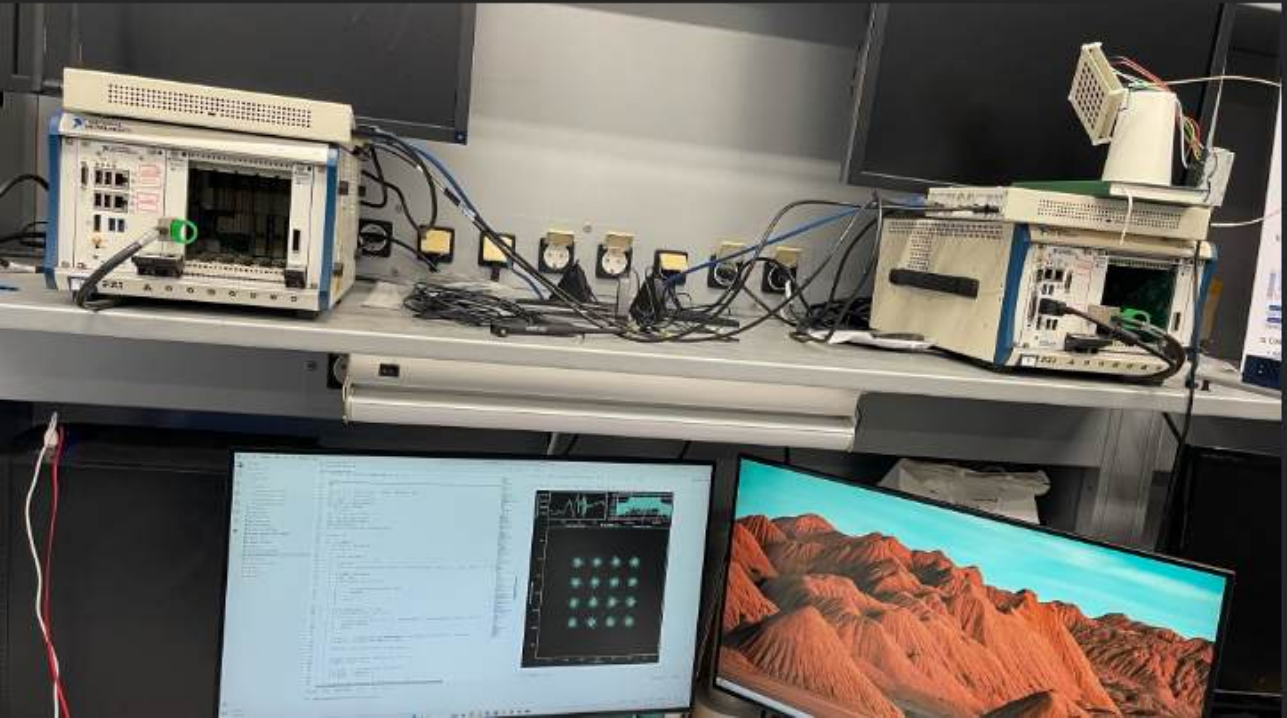

Fluid Antenna Systems (FAS) Redefining Wireless Communications

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London, United Kingdom

Chair of TCCN SIG on FAS
Chair of WTC SIG on FAS

A Peek into the 6G World

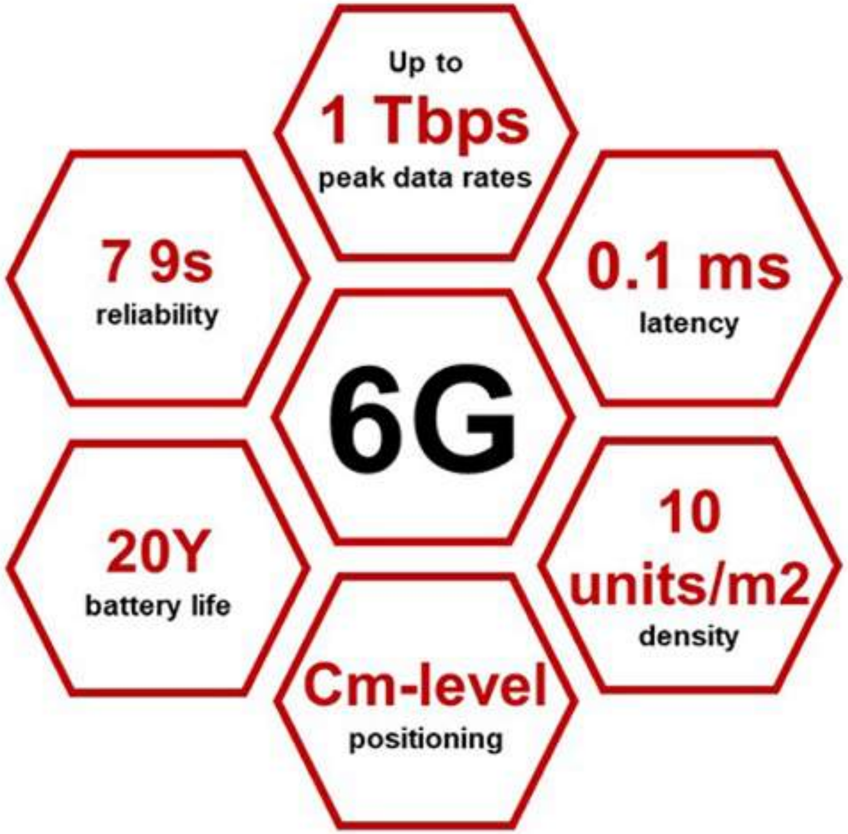
Integration of physical and digital worlds

- AI (artificial intelligence)
- ISAC (integrated sensing and communications)
- IC (immersive communication)
- HRLLC (hyper-reliable low-latency communications)
- MC (massive communications)
- UC (ubiquitous communications)

What Do We Want in 6G?

- TKμ extreme connectivity
  - Tbps-scale data rate
  - Kbps/Hz-scale spectral efficiency
  - μs-scale latency

You X. *et al.*, "**Toward 6G TKμ extreme connectivity: Architecture, key technologies and experiments**," IEEE Wireless Communications, vol. 30, no. 3, pp. 86–95, June 2023.



Extreme Access

- 6G aims to achieve 1000+ bps/Hz

$$\log_2(1+\mathrm{SNR}) = 1000$$
$$\rightarrow \mathrm{SNR} \approx 3000 \text{ dB}$$

- How about?

$$U \log_2(1+\mathrm{SINR}) = 1000$$
$$\rightarrow U = 1000 \text{ and } \mathrm{SINR} \approx 0 \text{ dB}$$

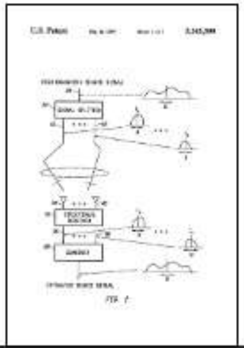
A Battle over Interference

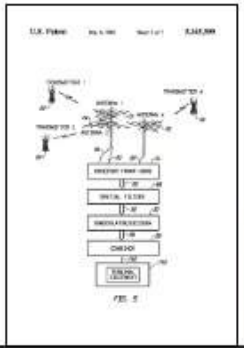
MIMO

- Professors A. Paulraj and T. Kailath are Fathers of MIMO
  - Patent US5345599A filed 1992, granted 1994, expired 2012
- The interest of MIMO research exploded in 1998 after Foschini's work

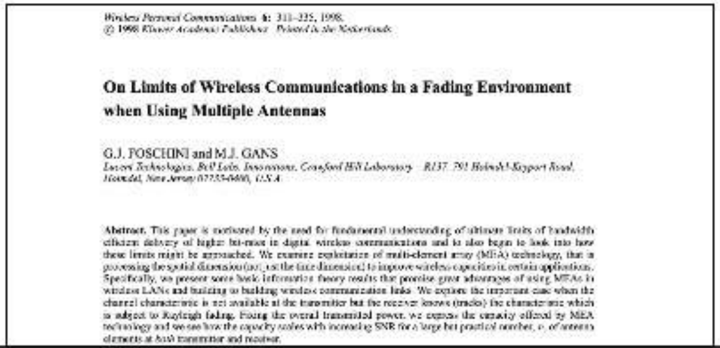
G. J. Foschini, "**Layered space-time architecture for wireless communication in a fading environment when using multi-element antennas**," Bell Labs Technical Journal, pp. 41–59, October 1996.

G. J. Foschini, and M. J. Gans, "**On limits of wireless communications in a fading environment when using multiple antennas**," Wireless Personal Communications, vol. 6, no. 3, pp. 311–335, March 1998.





Emeritus Professor of Stanford University



Wireless Personal Communications 6: 311–335, 1998.
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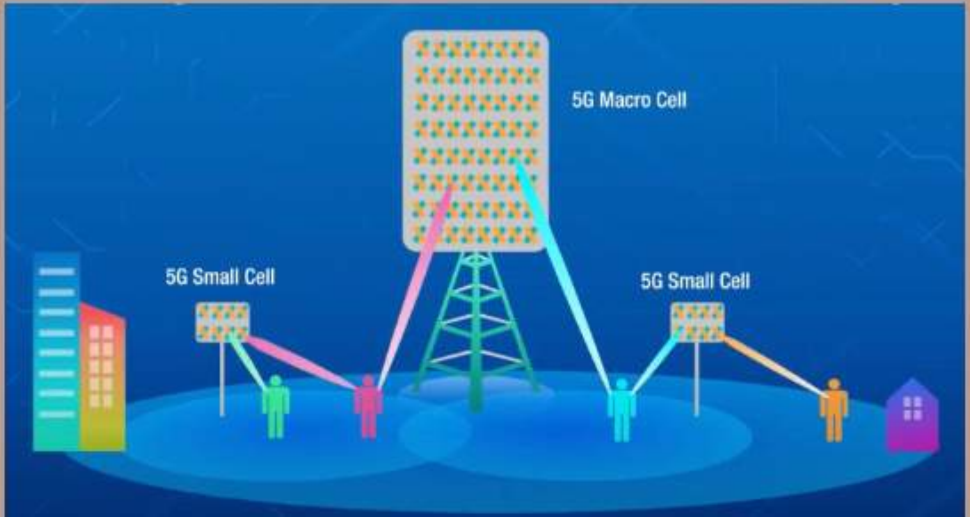
On Limits of Wireless Communications in a Fading Environment when Using Multiple Antennas

G.J. FOSCHINI and M.J. GANS
Lucent Technologies, Bell Labs. Innovations, Crawford Hill Laboratory – R137, 791 Holmdel-Keyport Road, Holmdel, New Jersey 07733-0400, U.S.A.

Abstract. This paper is motivated by the need for fundamental understanding of ultimate limits of bandwidth efficient delivery of higher bit-rates in digital wireless communications and to also begin to look into how these limits might be approached. We examine exploitation of multi-element array (MEA) technology, that is processing the spatial dimension (not just the time dimension) to improve wireless capacities in certain applications. Specifically, we present some basic information theory results that promise great advantages of using MEAs in wireless LANs and building to building wireless communication links. We explore the important case when the channel characteristic is not available at the transmitter but the receiver knows (tracks) the characteristic which is subject to Rayleigh fading. Fixing the overall transmitted power, we express the capacity offered by MEA technology and we see how the capacity scales with increasing SNR for a large but practical number, n, of antenna elements at both transmitter and receiver.

Distinguished Inventor of Nokia Bell-Labs

NOKIA Bell Labs



Existing Technologies

- MU-MIMO (2000 & 2004) is being used in 802.11ac (Wi-Fi 5), 802.11ax (Wi-Fi 6), 802.11be (Wi-Fi 7), 4G and 5G
  - 5G uses 64 BS antennas to support up to 12 users on the same physical data channel
  - Reliable CSI needed
  - Very expensive
  - Not quite scalable
- NOMA, RSMA, etc.

Interesting Observations on in

6G Reset
Gustavo Costa • 2nd
2d •
Join

What can we do better in 6G than 5G? Well, it all comes down to complexity.

Generally, when we think of a next generation of technology we tend to focus on "more": more capacity, more features, more spectrum, more services, more use cases and so on...
We are, however, paying an increasingly steep price for our desire for more: namely, complexity.
It was quite an a-ha moment. One of these days I was comparing the Rel-15 to the Rel-18 versions of TS 38.321 (5G NR MAC specification) and I realized something: Wow! It used to have only about 80 pages! (now at more than 340).
I decided to check and plot (see the graph below) what has been happening to specs. I ´ve chosen these ones as small but representative sample:

The trend is the same for all specifications – their page count has been increasing at a fast pace. And it is not that we have started simple. If you compare 5G NR to 4G LTE – many things which were fixed in 4G have 2, 3 or many options in 5G. Often, initial 5G specs may have double the number of pages of equivalent 4G ones. Also, it is striking that Rel-15 felt incomplete and each spec pretty much doubled for Rel-16.
Naturally, each of these decisions had a story of reasons, discussions and compromises behind it. But cumulatively we have been adding complexity at a higher pace than we can grasp or than we need.
One of the most interesting contributions to

Comments — Most relevant

Robert Heath • 1st — 1d
Charles Lee Powell Chair in Wireless C...

We had a related discussion at WCNC 2025. Wen Tong made the point that the entire 5G spec if printed would be 22m high. I checked on chatGPT and it seemed that the 802.11 spec if printed is about 22cm. I asked why 80% of wireless Internet traffic goes on 802.11 and the spec is 100x more compressed. Generated some interesting discussion.

Like • 7 | Reply • 2 replies

Expensive RF Chains

- A **large** antenna array at your mobile phone is not affordable

📡 **Estimated RF Chain Cost Across Frequency Ranges (in EUR)**

Frequency Range (GHz)	Typical Use Case	Estimated RF Chain Cost (EUR)
< 6	4G / Sub-6 GHz 5G	€45 – €91
6 – 12	Mid-band 5G, Radar Systems	€73 – €137
24 – 30	5G mmWave Access	€137 – €228
57 – 71	WiGig (802.11ad/ay), Unlicensed mmWave	€228 – €364
90 – 110	THz Communications, High-Resolution Imaging	€364 – €546
130 – 150	Advanced THz Sensing, Research Applications	€546 – €819
180 – 220	Experimental Ultra-High Frequency Systems	€819 – €1,365

Network Densification

- A natural move to accommodate greater speed and capacity is to move to higher frequency bands, e.g., mmWave or even THz
  - Higher attenuation, shorter range

📶 **Base Station Cost vs Frequency (in EUR)**

Freq. Range (GHz)	Application	Coverage	Cost (EUR)
< 1	2G/3G, Rural 4G	> 10 km	€27,000 – €63,700
1 – 6	4G LTE, 5G Sub-6 GHz	1 – 5 km	€18,200 – €54,600
24 – 30	5G mmWave (dense urban)	100 – 300 m	€22,750 – €45,500
57 – 71	WiGig, FWA	50 – 150 m	€9,100 – €22,750
90 – 110	THz comms, backhaul	< 100 m	€45,500 – €109,200
> 110	UHF / experimental systems	< 50 m	€91,000+

My Ambition

- Is a simple massive multiple access scheme possible?

Can extreme massive multiple access be accomplished without channel state information at the transmitter side, without centralised interference management and without successive interference cancellation at the user side?

What If I Tell You?

- Support 1000 users on the same physical channel
- No need for precoding optimisation (hence no need for CSI at BS)
- No need for power control or user clustering
- No need for SIC at the user side
- No need for interference management

A Brief History

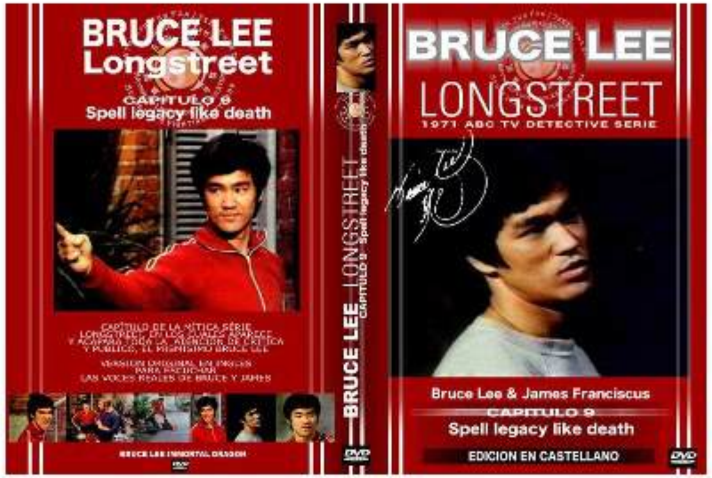
- First pattern-reconfigurable antenna (Rotman & Maestri 1960)
- Many ~~phased arrays~~ for satellite communications in 1970s-1980s
- Pixel antenna for adaptive MIMO (Cetiner et al. 2004)
- Flexible antenna spacing (Sayeed & Raghavan 2007)
- Pixel antennas for STC (Fazel, Grau, Jafarkhani, De Flaviis 2008)

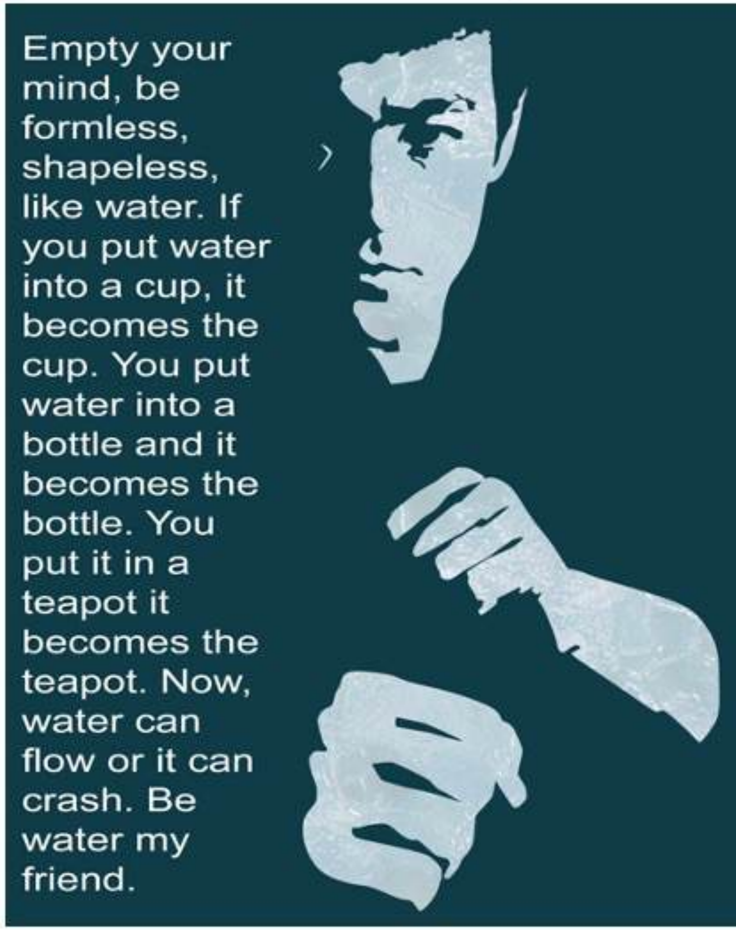
  …

- **Reconfigurable antennas** are limited to frequency, polarization and pattern

An Inspiration from Bruce Lee

- Bruce Lee once used a TV show to demonstrate Jeet Kune Do to a television audience, and expound the philosophy behind it
- The show, Longstreet, was aired in September 1971



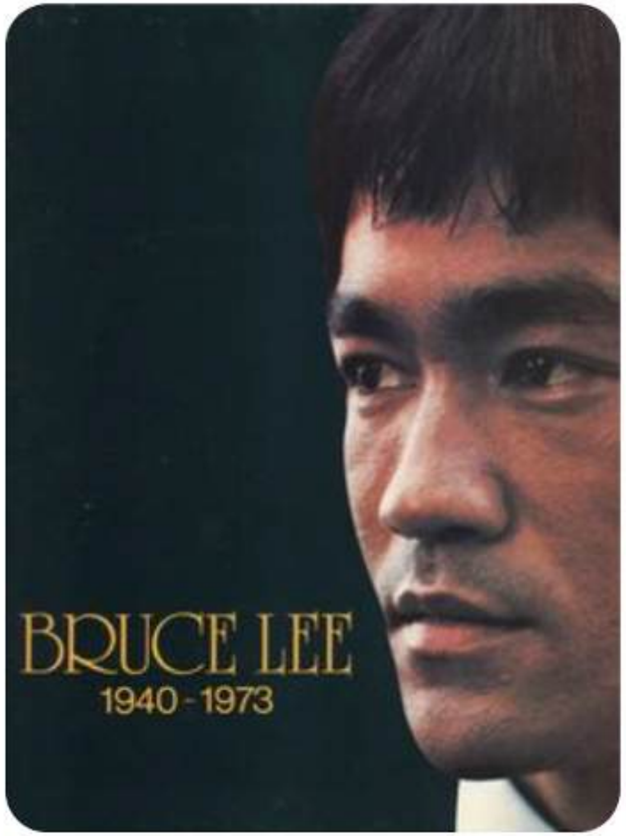


Fluid Antenna System (FAS)

- A new generation of reconfigurable antenna technologies
- **Shape-flexible position-flexible antenna** systems

1. K. K. Wong, K.-F. Tong, Y. Zhang, and Z. Zheng, "**Fluid antenna system for 6G: When Bruce Lee inspires wireless communications**," Electronics Letters, vol. 56, no. 24, pp. 1288–1290, November 2020.
2. K. K. Wong, A. Shojaeifard, K. F. Tong, and Y. Zhang, "**Performance limits of fluid antenna systems**," IEEE Communications Letters, vol. 24, no. 11, pp. 2469-2472, November 2020.
3. K. K. Wong, A. Shojaeifard, K. F. Tong, and Y. Zhang, "**Fluid antenna systems**," IEEE Transactions on Wireless Communications, vol. 20, no. 3, pp. 1950-1962, March 2021.
4. K. K. Wong, K.-F. Tong, Y. Shen, Y. Chen, and Y. Zhang, "**Bruce Lee-inspired fluid antenna system: Six research topics and the potentials for 6G**," Frontiers in Communications and Networking, vol. 3, no. 853416, March 2022.
5. W. K. New *et al.*, "**A tutorial on fluid antenna system for 6G networks: Encompassing communication theory, optimization methods and hardware designs**," IEEE Communications Surveys and Tutorials, 2024.

Be Water, My Antenna!




FLUID ANTENNA
SYSTEM
6G

Potential Applications

Potential Applications

- XL-MIMO
- NOMA
- RSMA
- AirComp
- SWIPT
- UAV
- PLS
- LLM
- ISAC
- MEC
- RIS
- IM
- FL/LLM
- FD
- …

A Tutorial on Fluid Antenna System for 6G Networks: Encompassing Communication Theory, Optimization Methods and Hardware Designs

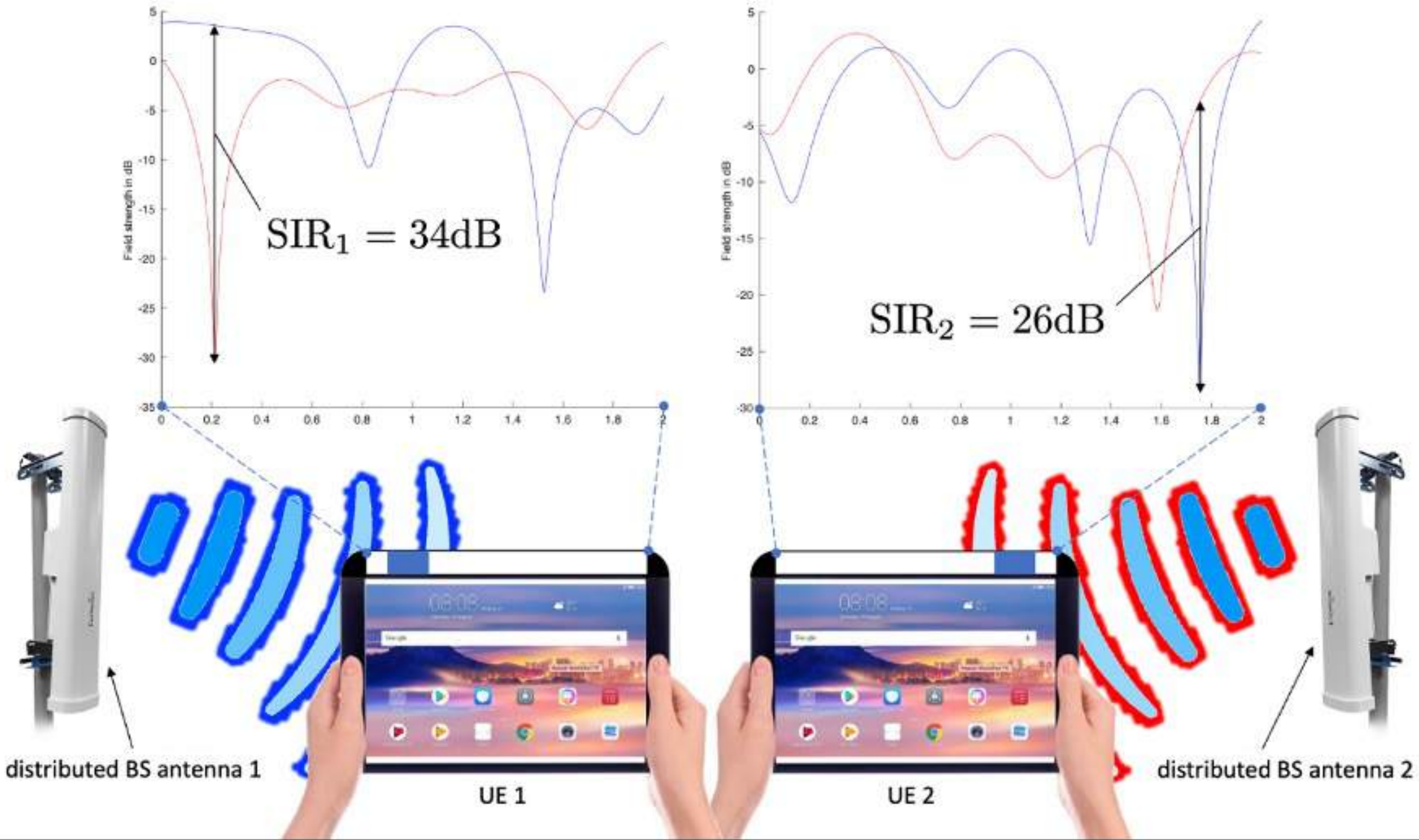
Wee Kiat New, *Member, IEEE*, Kai-Kit Wong, *Fellow, IEEE*, Hao Xu, *Member, IEEE*, Chao Wang, *Senior Member, IEEE*, Farshad Rostami Ghadi, *Member, IEEE*, Jichen Zhang, *Graduate Student Member, IEEE*, Junhui Rao, *Graduate Student Member, IEEE*, Ross Murch, *Fellow, IEEE*, Pablo Ramírez-Espinosa, David Morales-Jimenez, *Senior Member, IEEE*, Chan-Byoung Chae, *Fellow, IEEE*, and Kin-Fai Tong, *Fellow, IEEE*

***Abstract*—The advent of the sixth-generation (6G) networks presents another round of revolution for the mobile communication landscape, promising an immersive experience, robust reliability, minimal latency, extreme connectivity, ubiquitous coverage, and capabilities beyond communication, including intelligence and sensing. To achieve these ambitious goals, it is apparent that 6G networks need to incorporate the state-of-the-art technologies. One of the technologies that has garnered rising interest is fluid antenna system (FAS) which represents any software-controllable of freedom (dof) to harness diversity and multiplexing gains. In this paper, we provide a comprehensive tutorial, covering channel modeling, signal processing and estimation methods, information-theoretic insights, new multiple access techniques, and hardware designs. Moreover, we delineate the challenges of FAS and explore the potential of using FAS to improve the performance of other contemporary technologies. By providing insights and guidance, this tutorial paper serves to inspire researchers to explore new horizons and fully unleash the potential of FAS.**

IEEE Commun. Surv. & Tut. [Online] https://arxiv.org/pdf/2407.03449

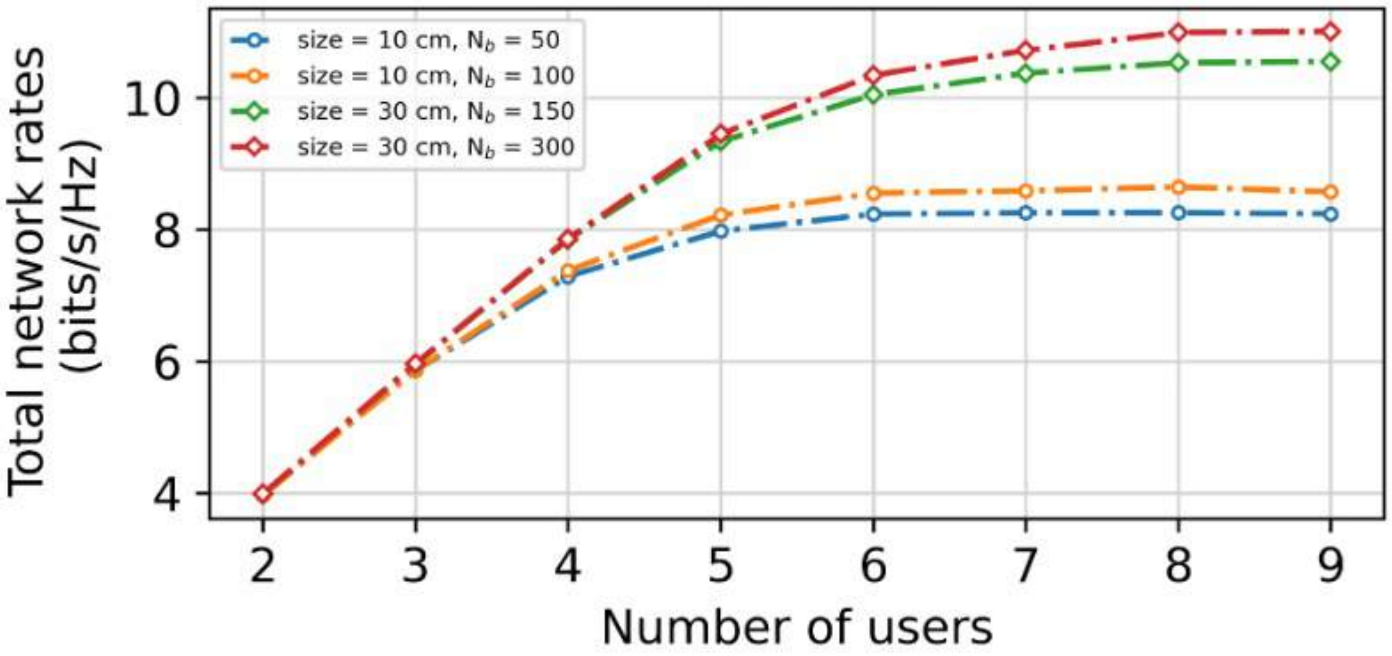
Slow Fluid Antenna Multiple Access

- K. K. Wong, and K. F. Tong, "**Fluid antenna multiple access**," IEEE Transactions on Wireless Communications, vol. 21, no. 7, pp. 4801-4815, July 2022.
- K. K. Wong, D. Morales-Jimenez, K. F. Tong, and C. B. Chae, "**Slow fluid antenna multiple access**," IEEE Transactions on Communications, vol. 71, no. 5, pp. 2831-2846, May 2023.



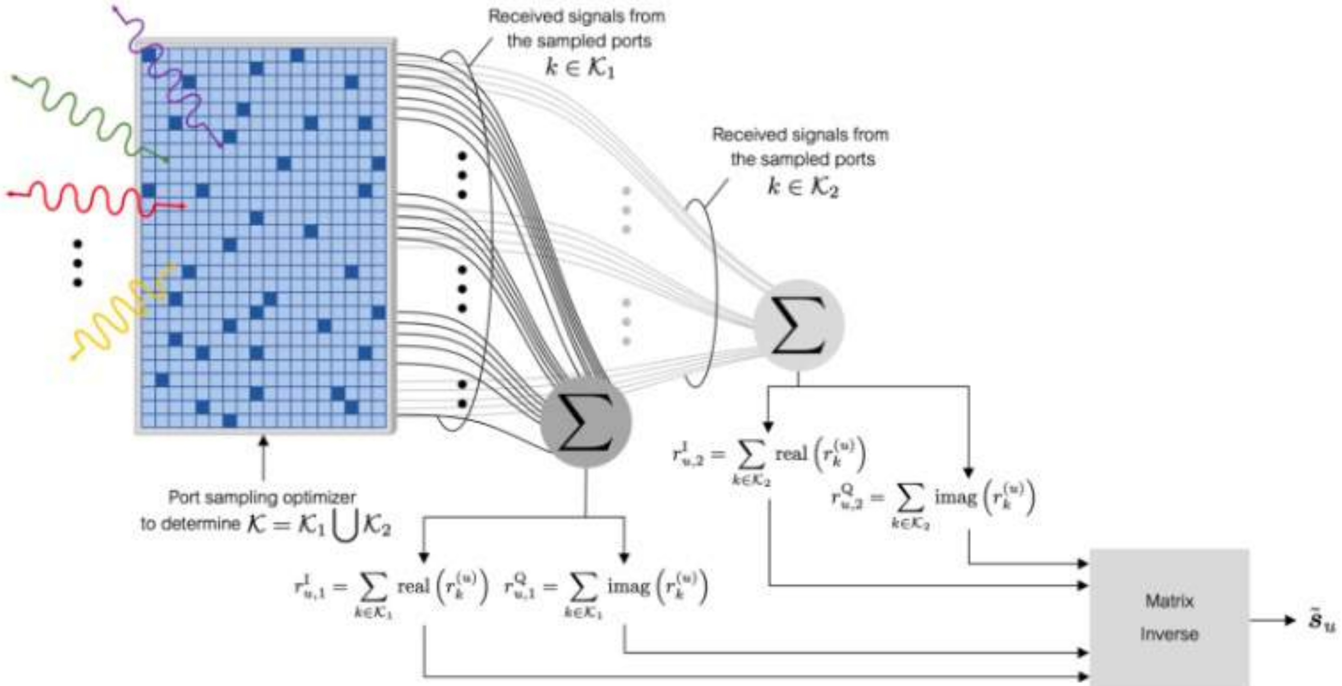
Good but Not Great

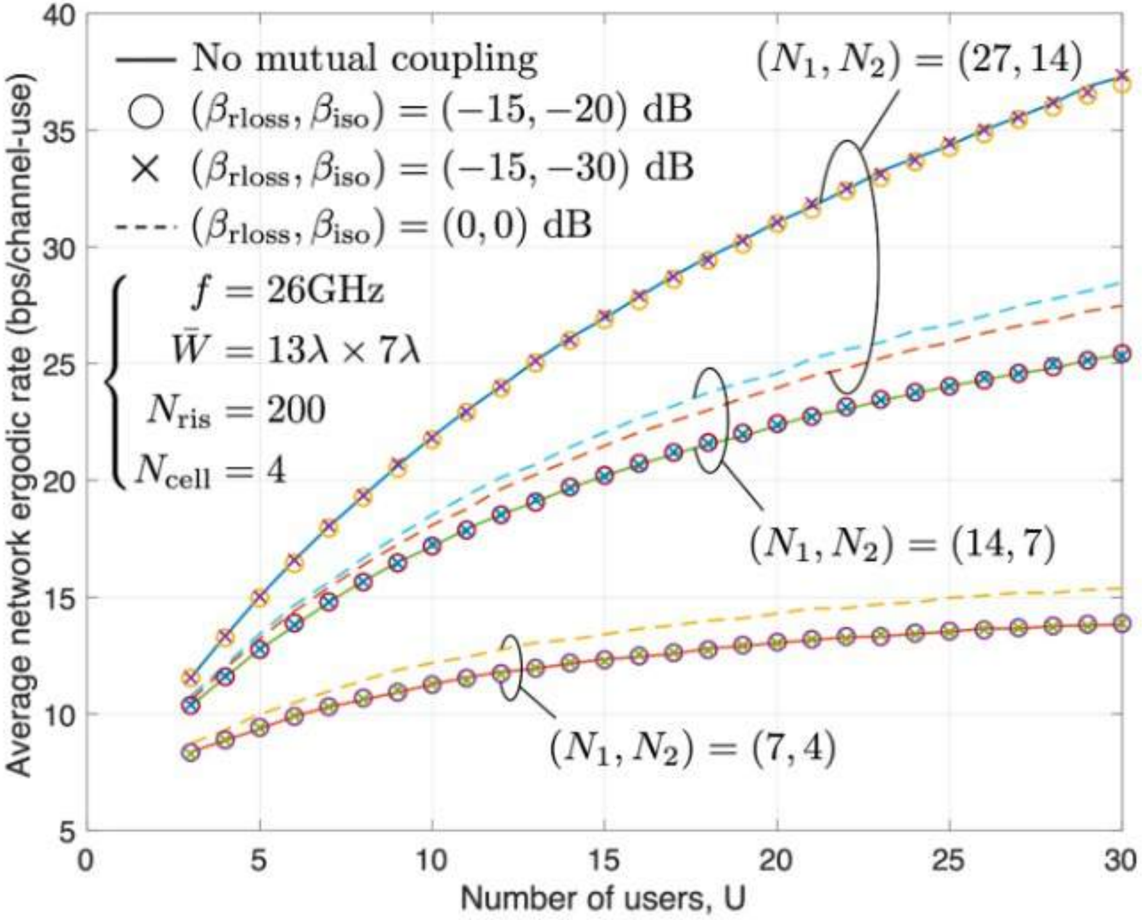
- With too many users, it will be impossible to find a port that the aggregate interference is sufficiently weak for a reliable link



CUMA

- K. K. Wong, C.-B. Chae, and K. F. Tong, "**Compact ultra massive antenna array: A simple open-loop massive connectivity scheme**," IEEE Transactions on Wireless Communications, vol. 23, no. 6279-6294, June 2024.
- K. K. Wong, "**Transmitter CSI-free RIS-randomized CUMA for extreme massive connectivity**," IEEE Open Journal of the Communications Society, vol. 5, pp. 6890-6902, 2024.

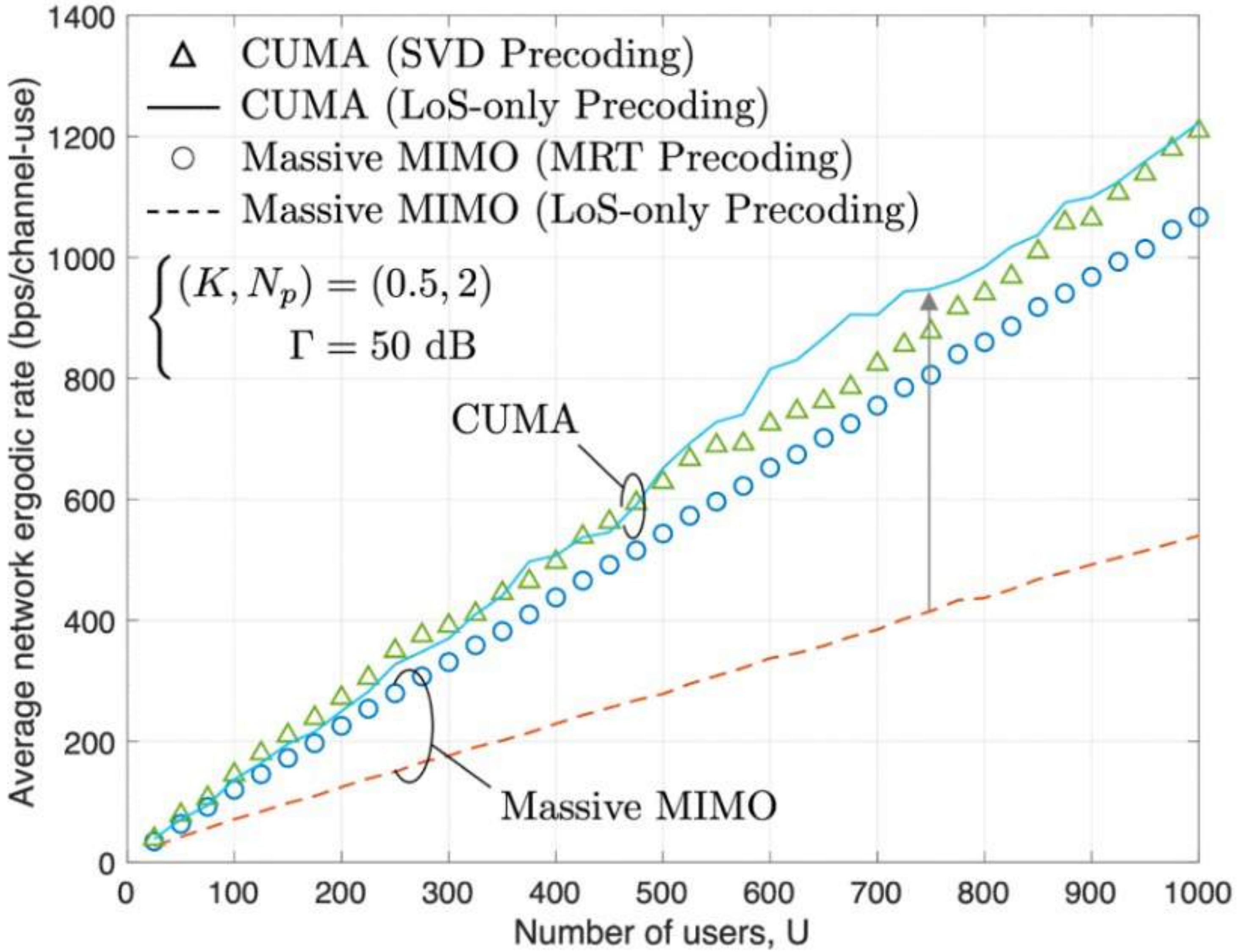




XL-MIMO + FAS

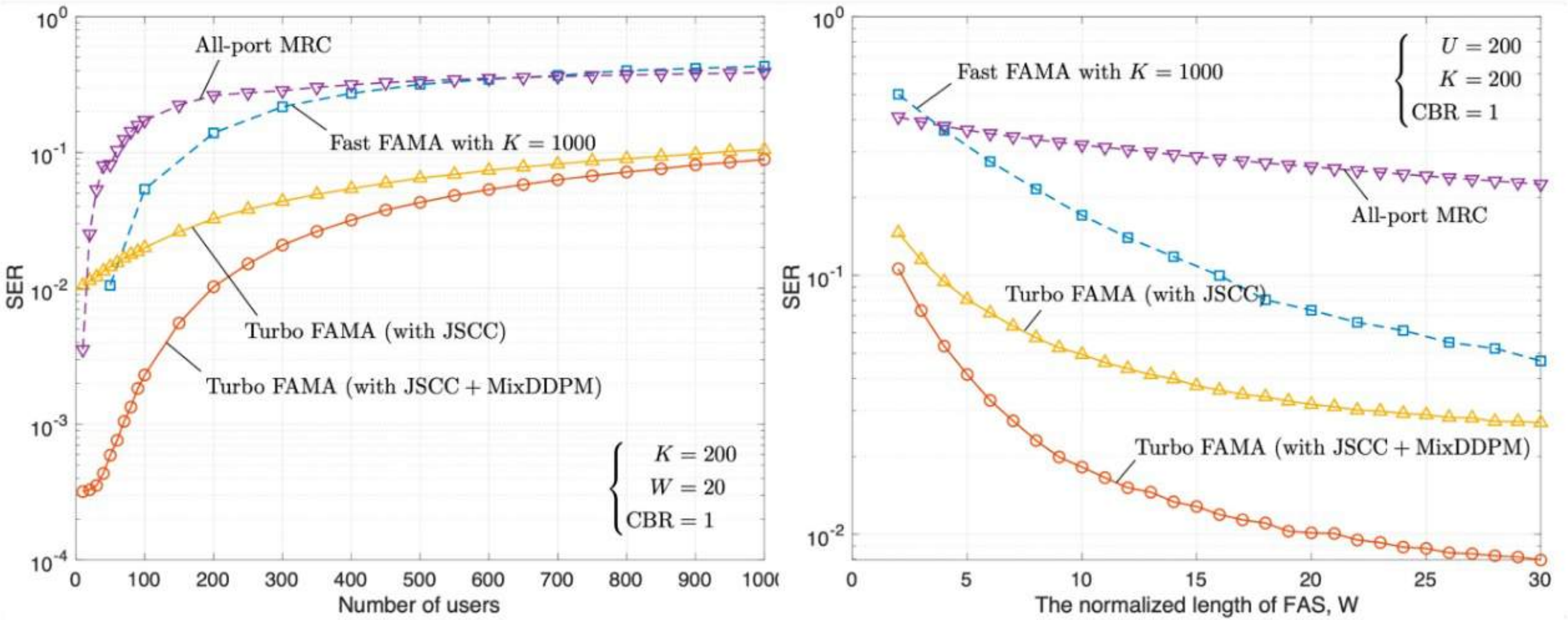
- Simplifies XL-MIMO
- Needs less CSI
- Supports 1000+ UEs
- Enhances performance

- W. K. New *et al.*, "**A tutorial on fluid antenna system for 6G networks: Encompassing communication theory, optimization methods and hardware designs**," [Online] arXiv:2407.03449, July 2024.



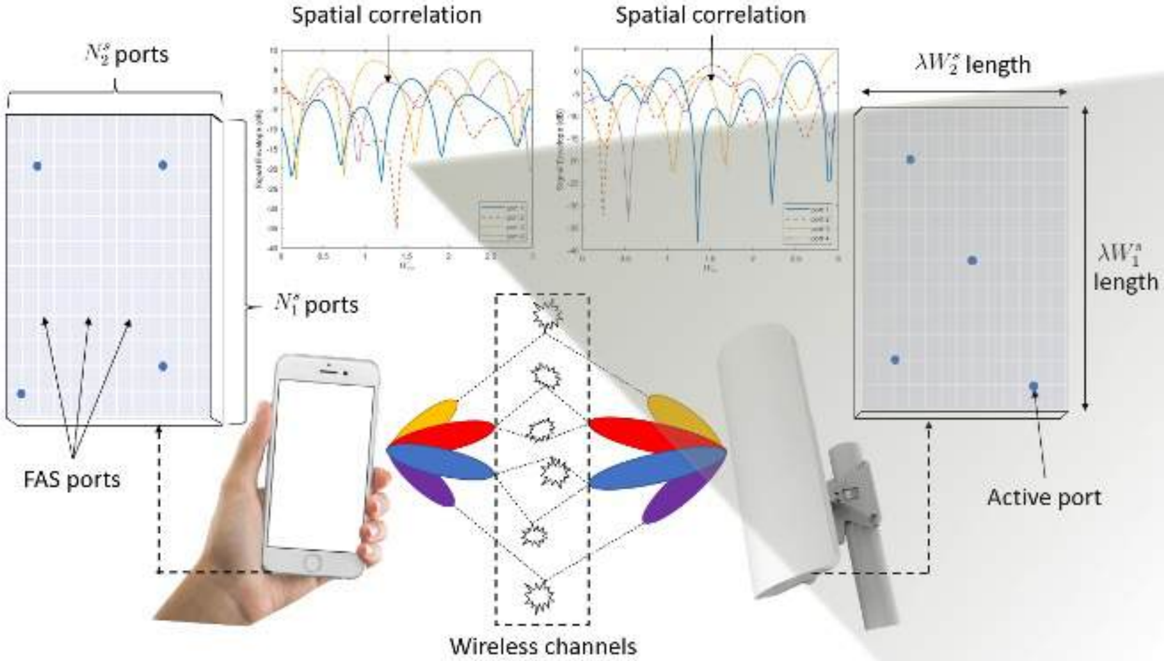
Turbo FAMA

- N. Waqar, K. K. Wong, C.-B. Chae, and R. Murch, "**Turbocharging fluid antenna multiple access**," arXiv preprint, arXiv:2504.04604, April 2025.



MIMO-FAS

- W. K. New, K. K. Wong, H. Xu, K. F. Tong, and C.-B. Chae, "**An information-theoretic characterization of MIMO-FAS: Optimization, diversity-multiplexing tradeoff and *q*-outage capacity**," IEEE Transactions on Wireless Communications, vol. 23, no. 6, pp. 5541-5556, June 2024.

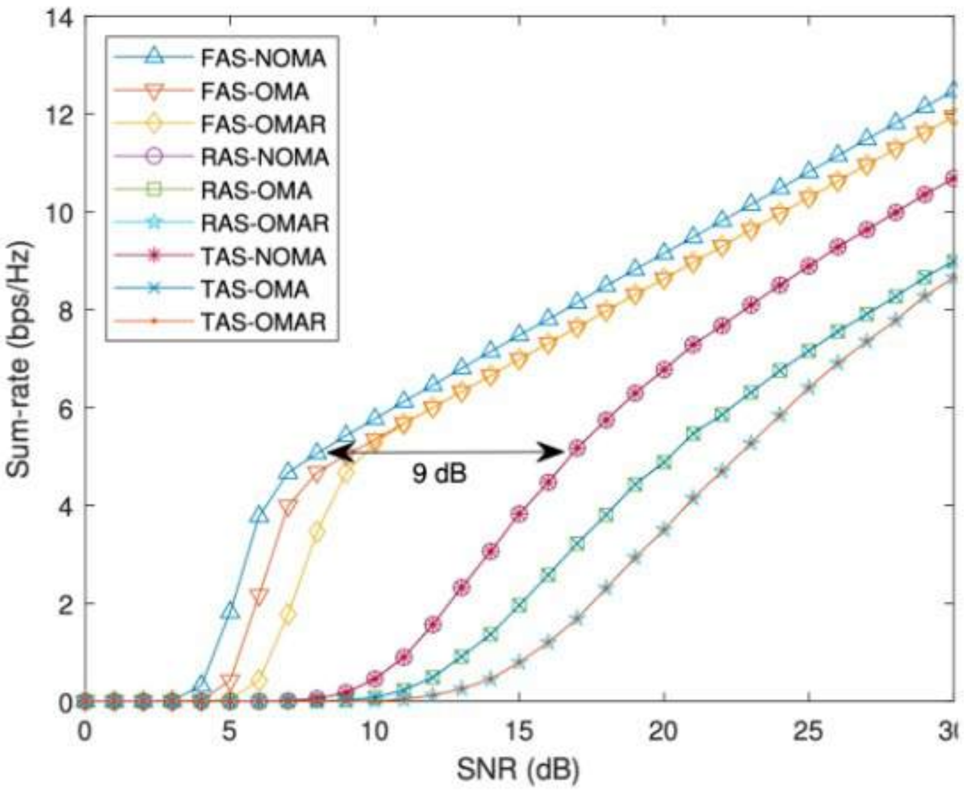


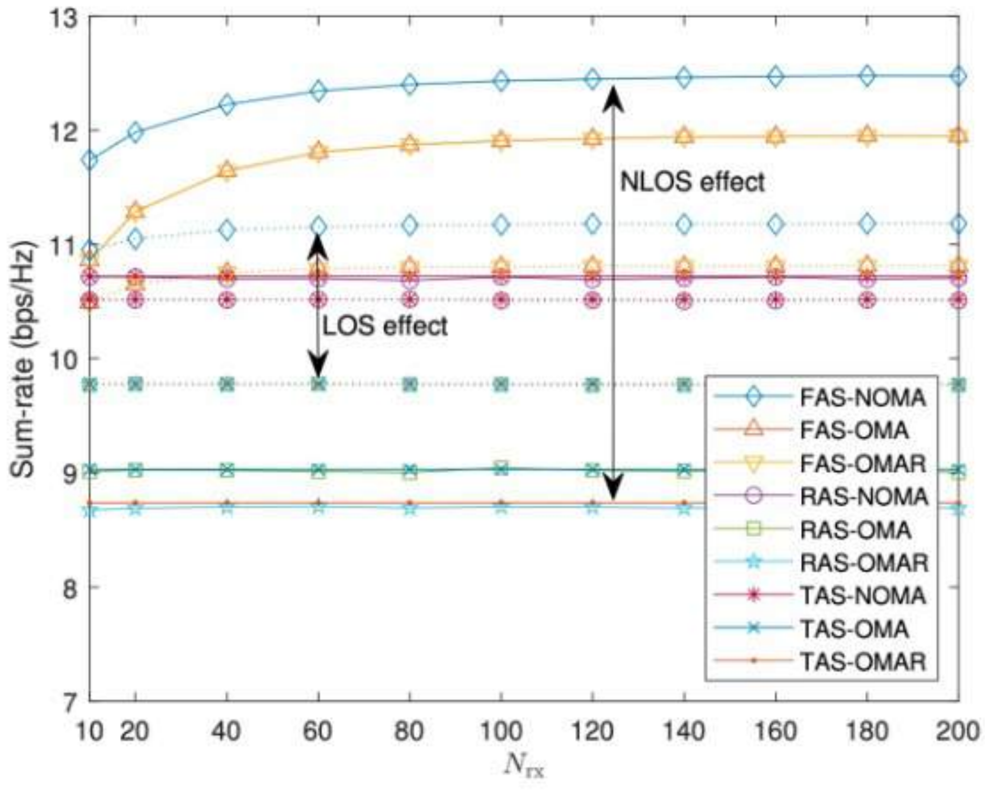
Diversity Order

Size	MIMO	MIMO-FAS
$0.5\lambda \times 0.5\lambda$	$4 \times 4 = 16$	$13 \times 13 = 169$
$1\lambda \times 1\lambda$	$9 \times 9 = 81$	$23 \times 23 = 529$
$1.5\lambda \times 1.5\lambda$	$16 \times 16 = 256$	$34 \times 34 = 1156$
$2\lambda \times 2\lambda$	$25 \times 25 = 625$	$48 \times 48 = 2304$
$2.5\lambda \times 2.5\lambda$	$36 \times 36 = 1296$	$60 \times 60 = 3600$
$3\lambda \times 3\lambda$	$49 \times 49 = 2401$	$73 \times 73 = 5329$

FAS + NOMA

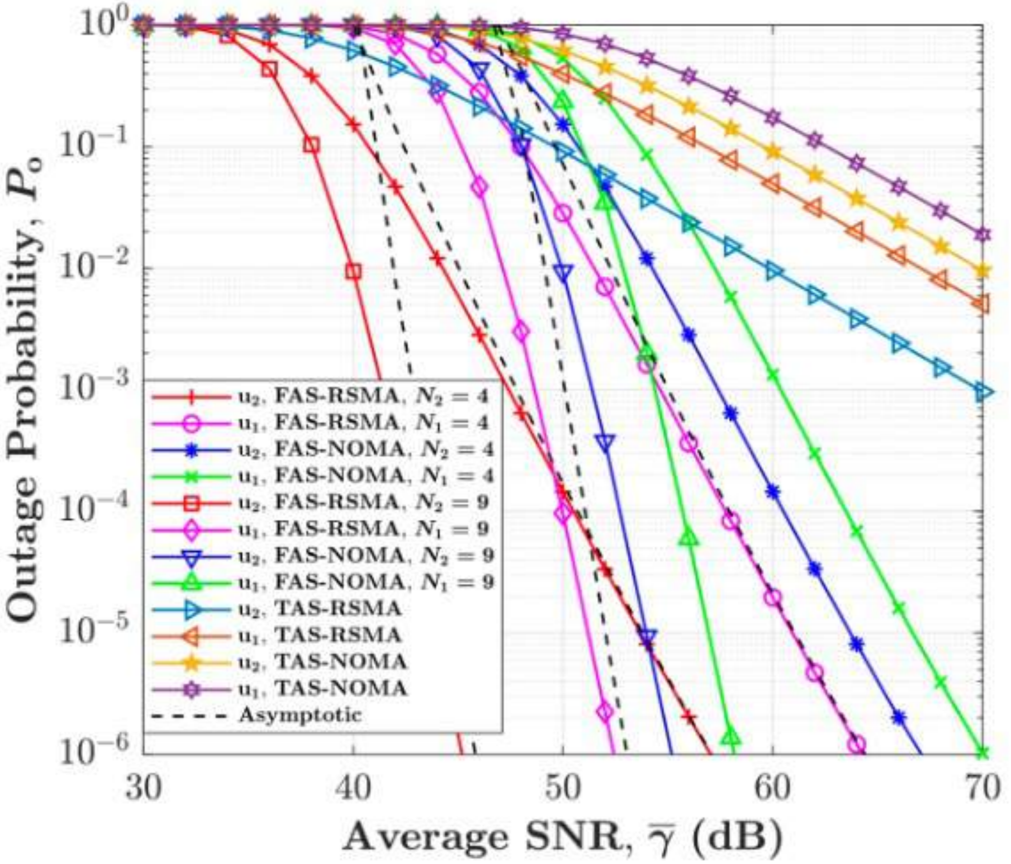
- W. K. New, K. K. Wong, H. Xu, K. F. Tong, C.-B. Chae, and Y. Zhang, "**Fluid antenna system enhancing orthogonal and non-orthogonal multiple access**," IEEE Communications Letters, vol. 28, no. 1, pp. 218-222, January 2024.

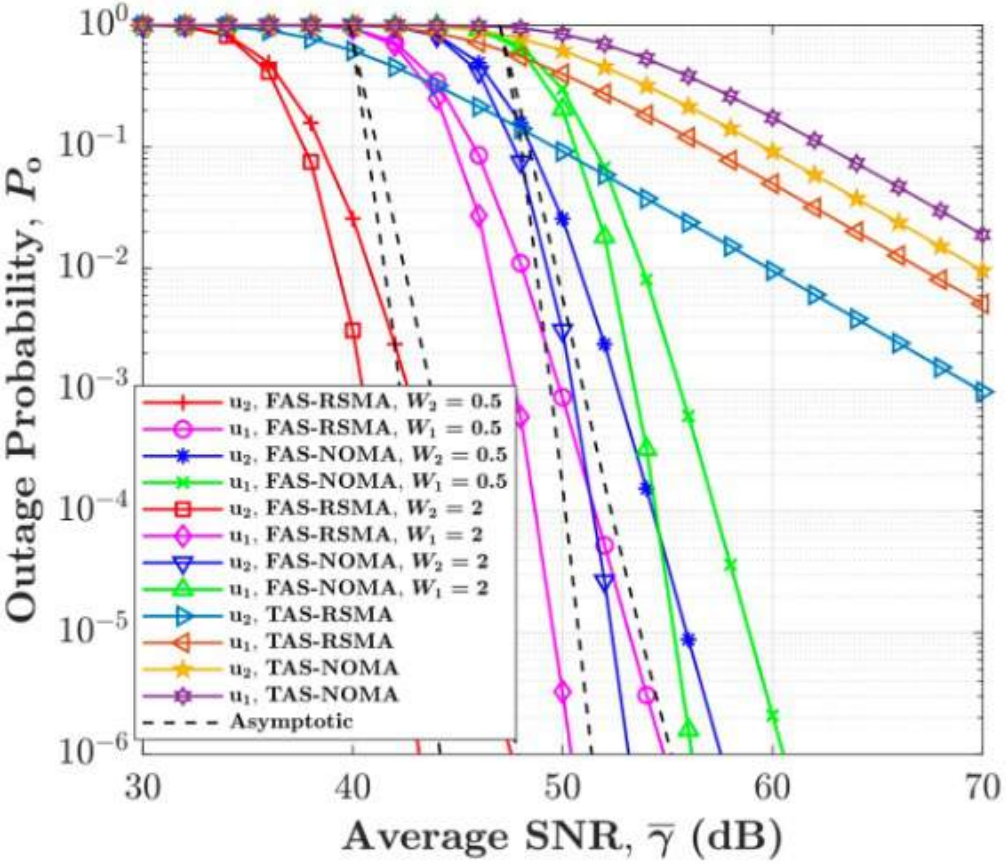




FAS + RSMA

- F. R. Ghadi, K. K. Wong, F. J. López-Martínez, L. Hanzo, and C.-B. Chae, "**Fluid antenna-aided rate-splitting multiple access**," submitted to IEEE Transactions on Vehicular Technology, 2024.

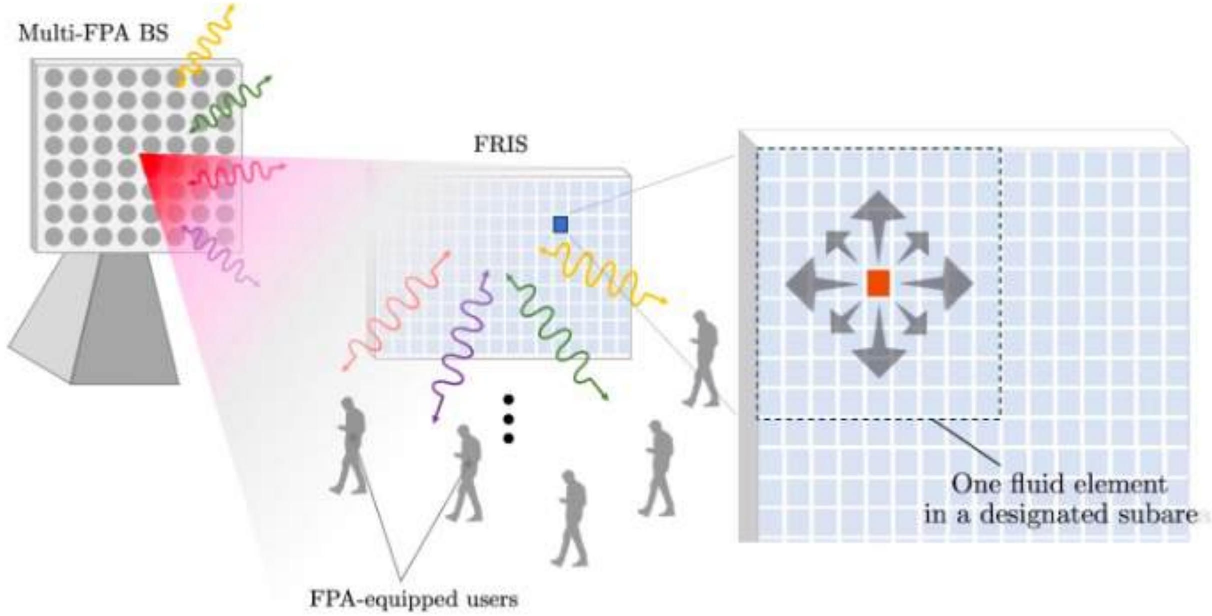




Fluid RIS

- A. Salem, K. K. Wong, G. Alexandropoulos, C.-B. Chae, and R. Murch, "**A first look at the performance enhancement potential of fluid reconfigurable intelligent surface**," arXiv:2502.17116, Feb. 2025.
- H. Xiao, X. Hu, K. K. Wong, H. Hong, G. C. Alexandropoulos, C.-B. Chae, "**Fluid reconfigurable intelligent surfaces: Joint on-off selection and beamforming with discrete phase shifts**," arXiv:2503.14601, Mar. 2025.

- Liberate the position of each element to unleash more diversity



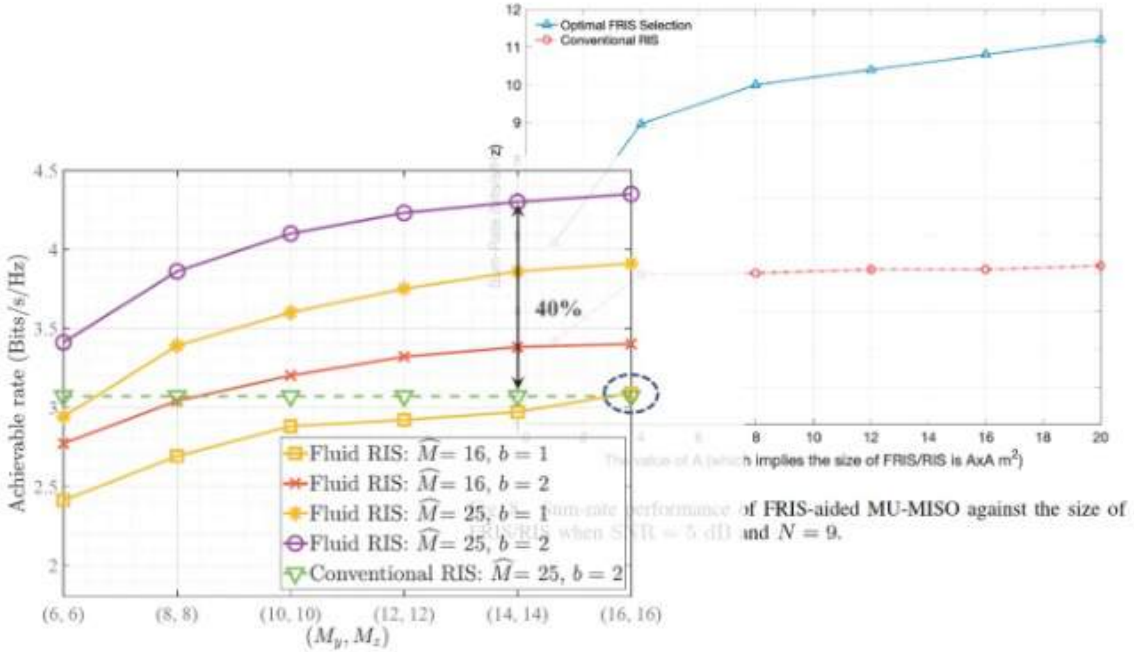
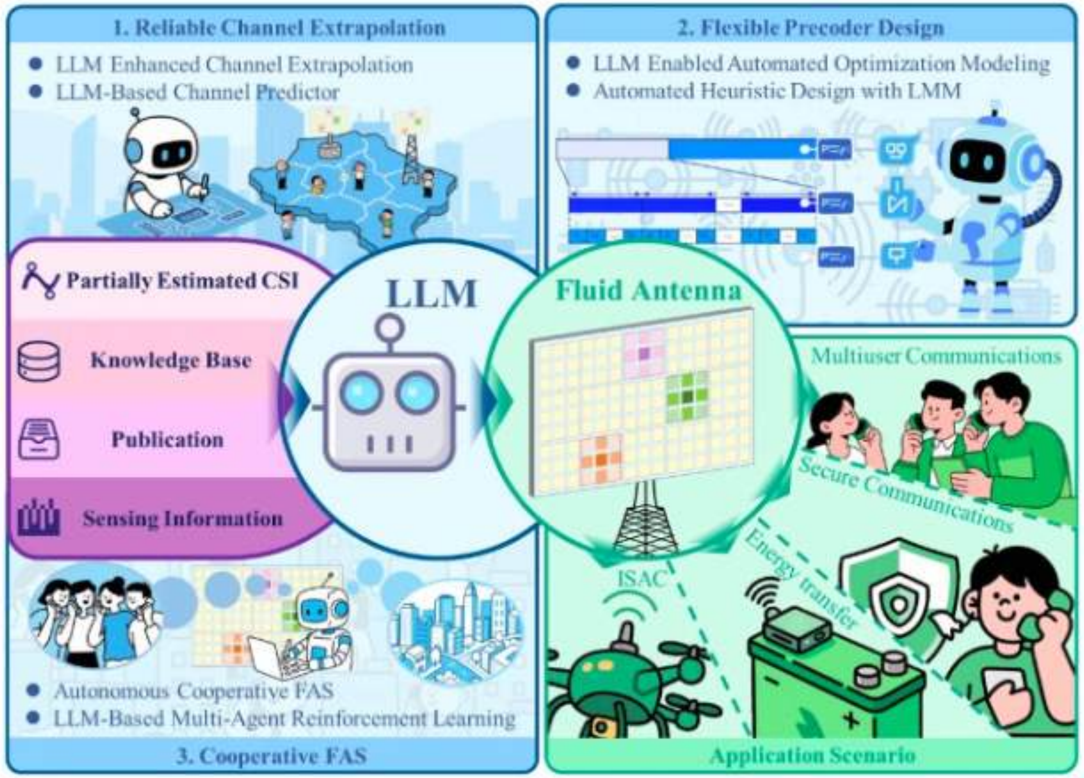
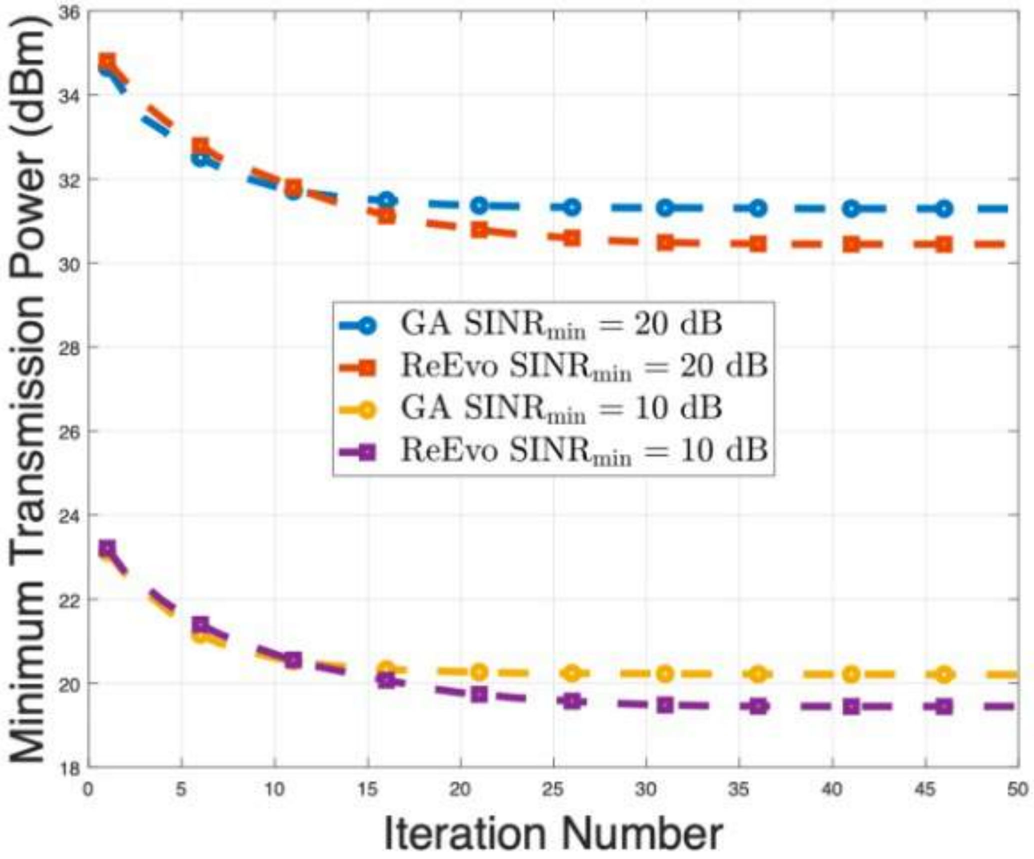


Fig. 2. The achievable rate versus the number of elements equipped at the RIS system considering different $\widehat{M}$ and phase-shift resolutions b.

LLM for FAS

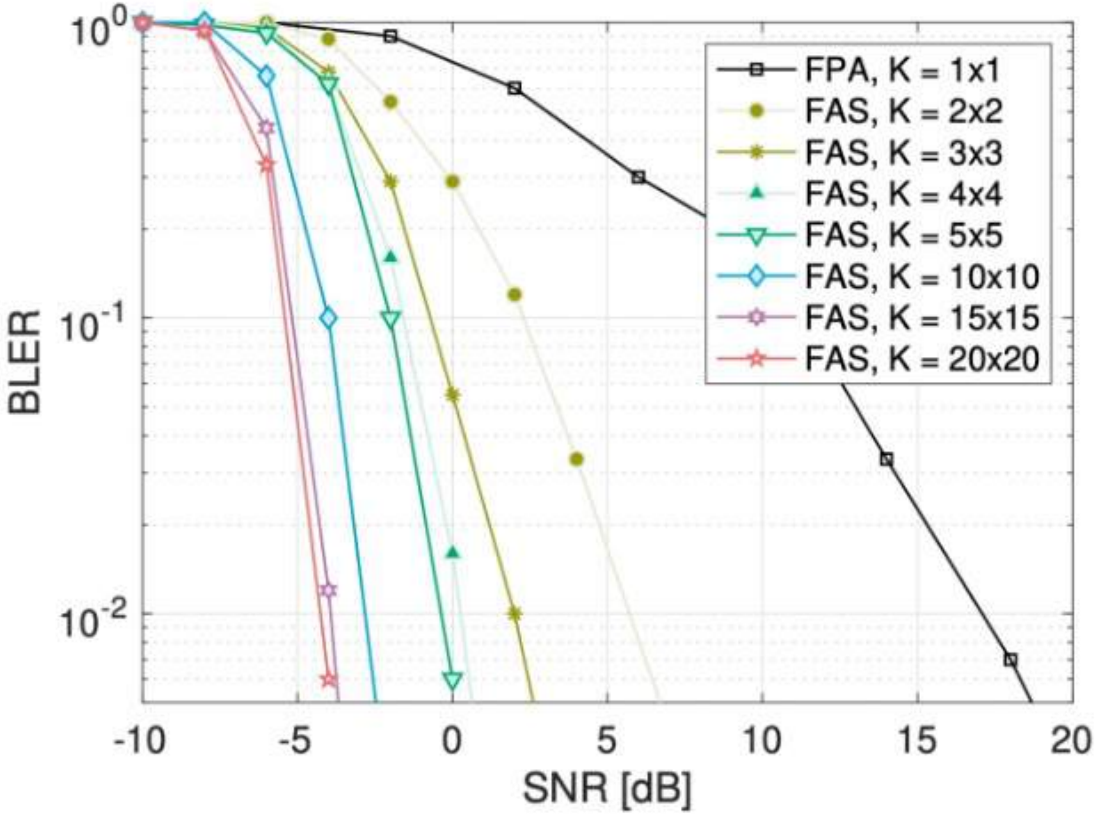


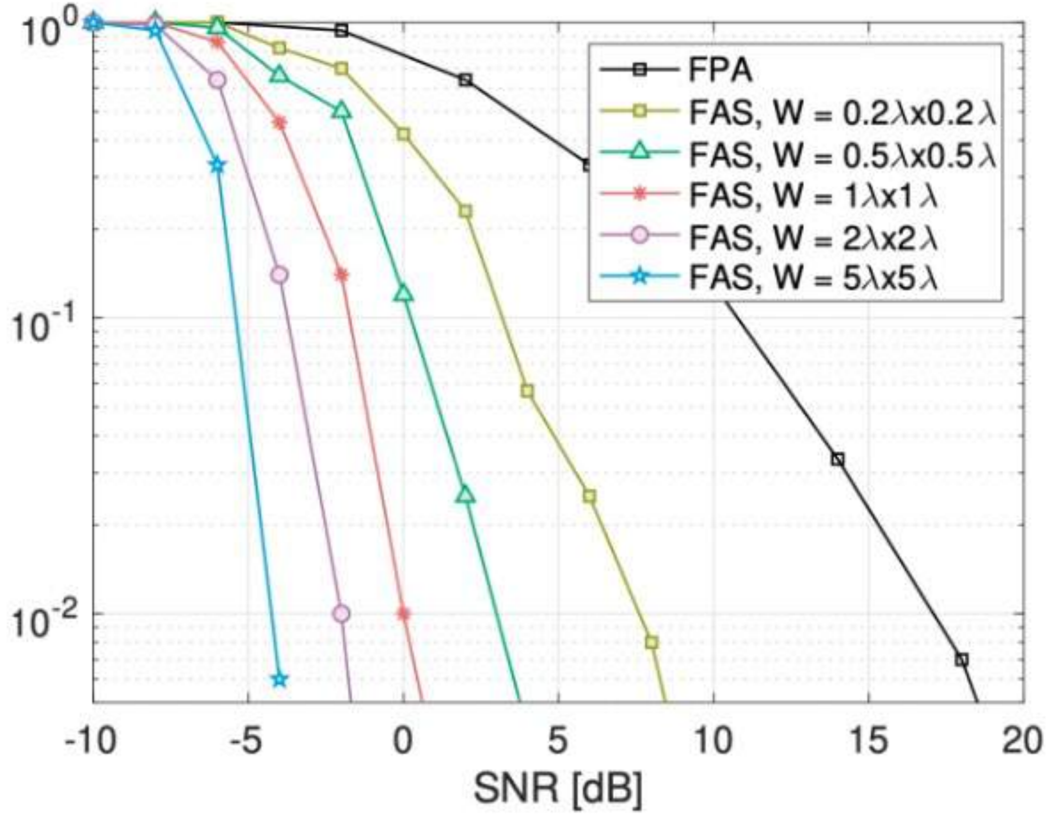


☞ https://drwangchao.github.io/LLLMDOFAS/

FAS + OFDM

- H. Hong, K. K. Wong, H. Li, H. Xu, H. Xiao, H. Shin, K.-F. Tong, and Y. Zhang, "**FAS meets OFDM: Enabling wideband 5G NR**," IEEE Transactions on Communications, arXiv:2503.05384, 2025.





FAMA + OFDM

- H. Hong, K. K. Wong, H. Xu, Y. Xu, H. Shin, R. Murch, D. He, and W. Zhang, "**Downlink OFDM-FAMA in 5G-NR systems**," IEEE Transactions on Wireless Communications, doi:10.1109/TWC.2025.3577771, 2025.

TDL-C* channel Profiles

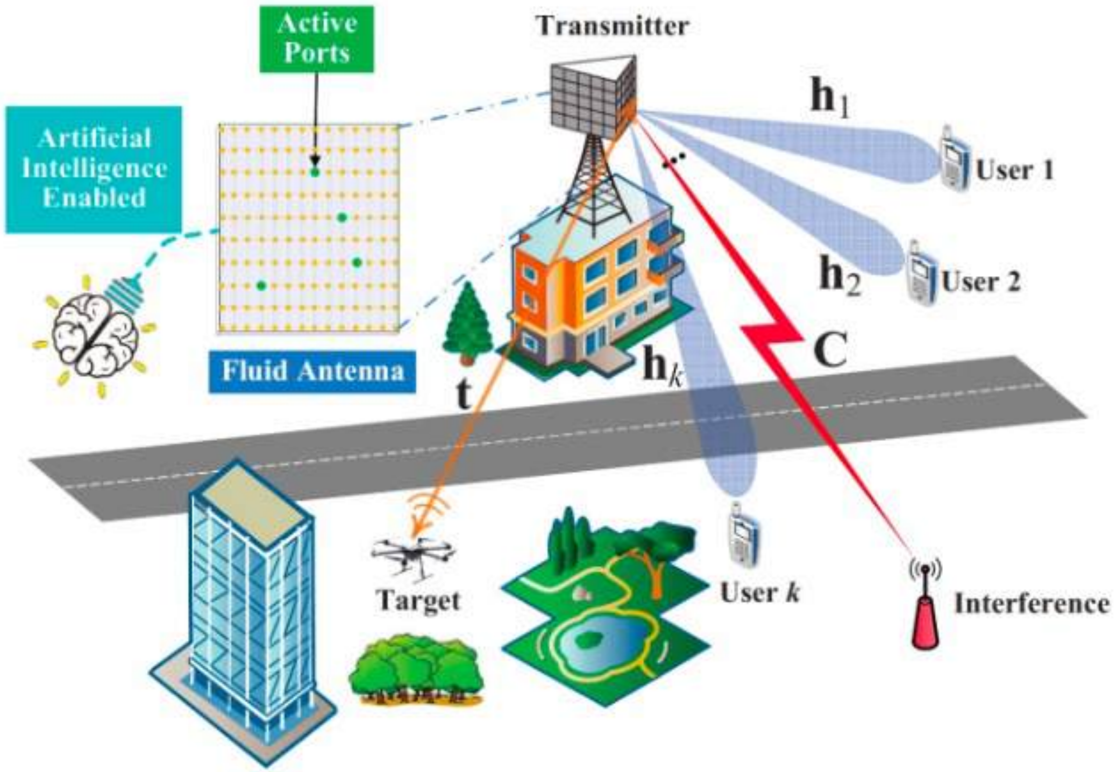
Tap #	Normalized delays	Power in [dB]	Fading distribution
1	0	-4.4	Rayleigh
2	0.2099	-1.2	Rayleigh
3	0.2219	-3.5	Rayleigh
4	0.2329	-5.2	Rayleigh
5	0.2176	-2.5	Rayleigh
6	0.6366	0	Rayleigh
7	0.6448	-2.2	Rayleigh
8	0.6560	-3.9	Rayleigh
9	0.6584	-7.4	Rayleigh
10	0.7935	-7.1	Rayleigh
11	0.8213	-10.7	Rayleigh
12	0.9336	-11.1	Rayleigh
13	1.2285	-5.1	Rayleigh
14	1.3083	-6.8	Rayleigh
15	2.1704	-8.7	Rayleigh
16	2.7105	-13.2	Rayleigh
17	4.2589	-13.9	Rayleigh
18	4.6003	-13.9	Rayleigh
19	5.4902	-15.8	Rayleigh
20	5.6077	-17.1	Rayleigh
21	6.3065	-16	Rayleigh
22	6.6374	-15.7	Rayleigh
23	7.0427	-21.6	Rayleigh
24	8.6523	-22.8	Rayleigh

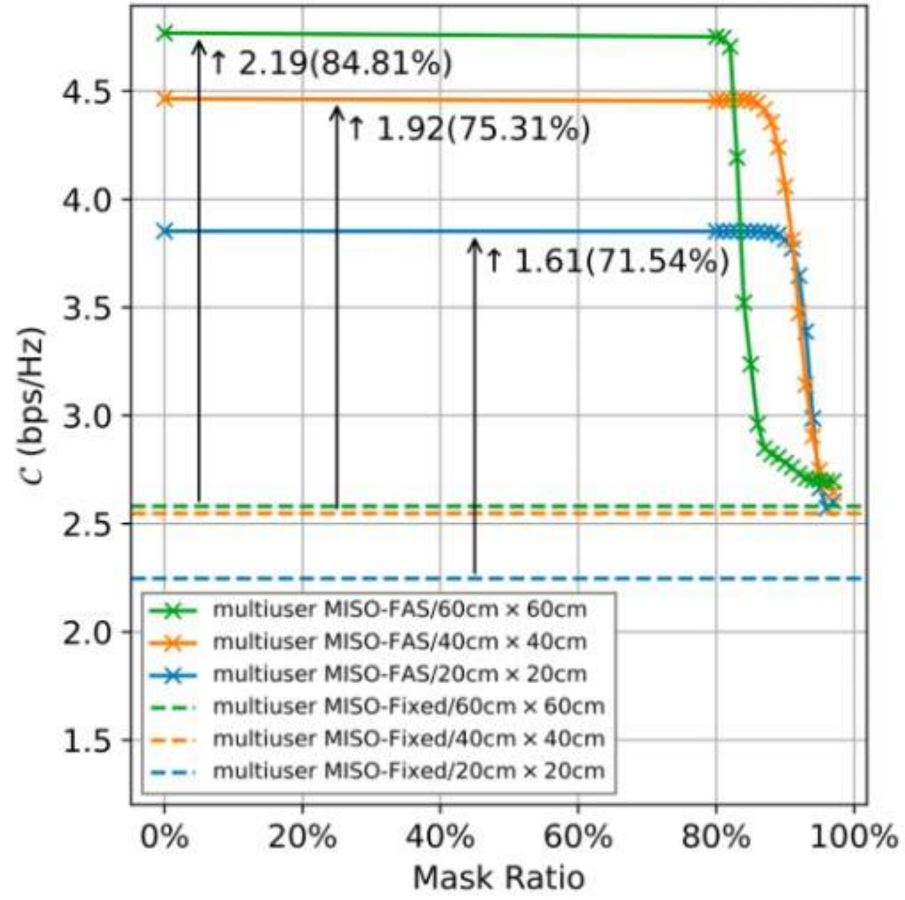
* 3GPP standardizes 5 TDL models for evaluations, in which three models, namely TDL-A, TDL-B and TDL-C, are constructed for NLOS, while the other two, namely TDL-D and TDL-E are constructed for LOS.

MCS Index I_{MCS}	Mod. Order Q_m	Target CR ×1024	TBS	SE [bit/s/Hz]	$W = [2,2]$						$W = [5,5]$					
					$N_{RF} = 16$		$N_{RF} = 4$		$N_{RF} = 2$		$N_{RF} = 16$		$N_{RF} = 4$		$N_{RF} = 2$	
					FAS	FPA	FAS	FPA	FAS	FPA	FAS	FPA	FAS	FPA	FAS	FPA
0	2	120	224	0.2222	46	41	20	6	14	2	80	42	32	6	21	2
1	2	157	288	0.2857	39	34	16	5	11	2	63	35	25	5	17	2
2	2	193	352	0.3492	35	30	14	5	10	2	53	31	21	5	15	2
3	2	251	456	0.4524	29	26	11	4	8	2	46	28	17	4	11	2
4	2	308	576	0.5714	25	23	9	4	6	2	36	24	14	4	9	2
5	2	379	704	0.6984	22	20	8	4	5	2	33	22	11	4	8	2
6	2	449	848	0.8413	20	18	7	4	5	2	28	20	10	4	7	2
7	2	526	984	0.9762	19	18	6	4	4	2	26	19	8	4	6	2
8	2	602	1128	1.1190	18	17	6	4	4	2	23	18	8	4	5	2
9	2	679	1256	1.2460	17	16	5	4	3	2	21	17	7	3	5	2
10	4	340	1256	1.2460	17	16	5	4	3	2	21	17	7	3	5	1
11	4	378	1416	1.4048	16	15	4	3	3	1	19	16	6	3	4	1
12	4	434	1608	1.5952	16	14	4	3	3	1	18	16	5	3	4	1
13	4	490	1800	1.7857	15	14	4	3	3	1	17	15	5	3	3	1
14	4	553	2024	2.0079	14	13	4	3	2	1	16	15	5	3	3	1
15	4	616	2280	2.2619	14	13	3	3	2	1	16	14	4	3	3	1
16	4	658	2408	2.3889	14	13	3	3	2	1	15	14	4	3	3	1
17	6	438	2408	2.3889	13	12	3	3	2	1	15	14	4	3	2	1
18	6	466	2536	2.5159	13	12	3	3	2	1	14	14	4	3	2	1
19	6	517	2856	2.8333	12	12	3	3	2	1	14	13	3	3	2	1
20	6	567	3104	3.0794	12	11	3	3	2	1	13	13	3	3	2	1
21	6	616	3368	3.3413	12	10	3	2	1	1	13	12	3	3	2	1
22	6	666	3752	3.7222	11	10	2	2	1	1	12	12	2	2	1	1
23	6	719	3968	3.9365	10	10	2	2	1	1	11	12	2	2	1	1
24	6	772	4224	4.1905	10	9	2	2	1	1	11	11	2	2	1	1
25	6	822	4608	4.5714	9	8	2	2	1	1	10	11	2	2	1	1
26	6	873	4864	4.8254	8	8	1	2	1	1	9	9	1	2	1	1
27	6	910	4992	4.9524	8	7	1	2	1	1	8	9	1	2	1	1
28	6	948	5248	5.2063	7	7	1	2	1	1	7	8	1	2	0	1

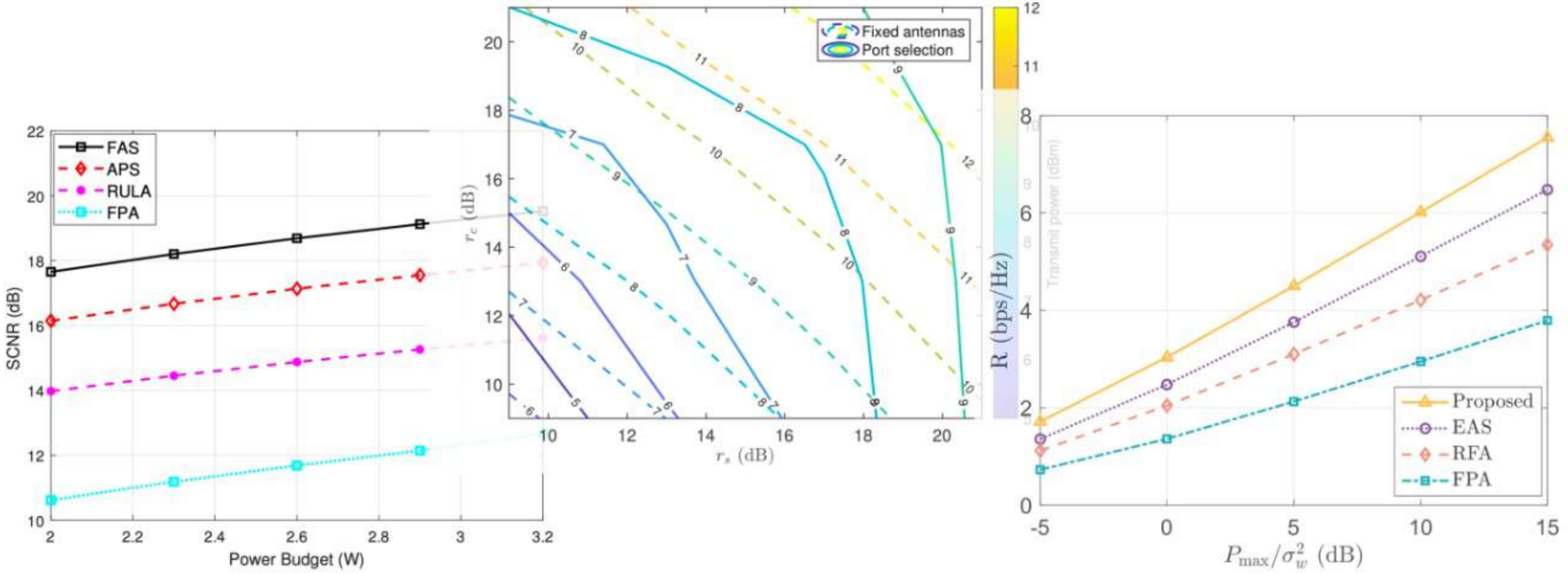
MU-MIMO + FAS for ISAC

- C. Wang, G. Li, H. Zhang, K. K. Wong, Z. Li, D. W. K. Ng, and C.-B. Chae, "**Fluid antenna system liberating multiuser MIMO for ISAC via deep reinforcement learning**," IEEE Transactions on Wireless Communications, vol. 23, no. 9, pp. 10879-10894, September 2024.





- L. Zhou, J. Yao, M. Jin, T. Wu, and K. K. Wong, "**Fluid antenna-assisted ISAC systems**," IEEE Wireless Communications Letters, vol. 13, no. 12, pp. 3533-3537, December 2024.
- J. Zou, H. Xu, C. Wang, L. Xu, S. Sun, K. Meng, C. Masouros, and K. K. Wong, "**Shifting the ISAC trade-off with fluid antenna systems**," IEEE Wireless Communications Letters, vol. 13, no. 12, pp. 3479-3483, December 2024.
- Y. Ye, L. You, H. Xu, A. Elzanaty, K. K. Wong, and X. Gao, "**SCNR maximization for MIMO ISAC assisted by fluid antenna system**," IEEE Transactions on Vehicular Technology, doi: 10.1109/TVT.2025.3557859, 2025.



Does FAS Actually Look Like This?

Prototypes: FAS is REAL

FAS can take many different forms!

- Liquid-based surface-wave enabled FAS

  Y. Shen *et al.*, "**Design and implementation of mmWave surface wave enabled fluid antennas and experimental results for fluid antenna multiple access**," [Online] arXiv:2405.09663, May 2024.

- Pixel reconfigurable antenna-based FAS

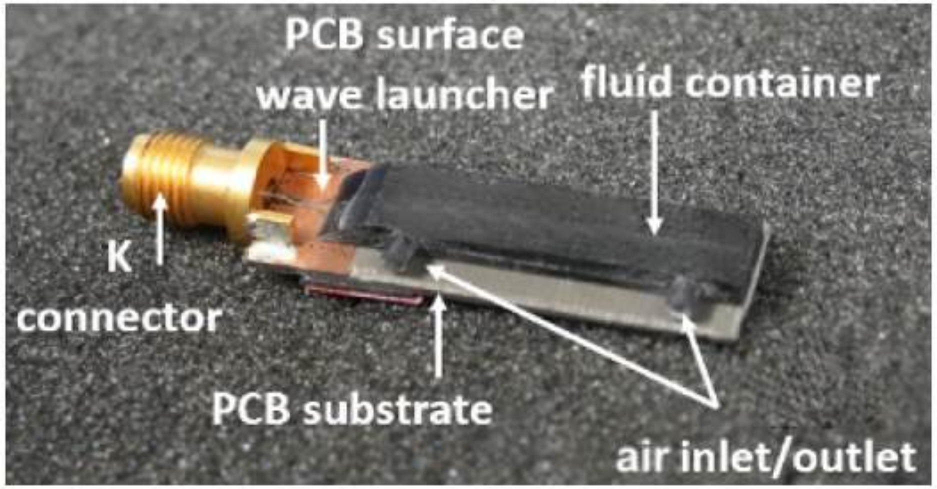
  J. Zhang *et al.*, "**A novel pixel-based reconfigurable antenna applied in fluid antenna systems with high switching speed**," IEEE Open Journal of Antennas and Propagation, Vol. 6, No. 1, pp. 212-228, Feb. 2025.

- Metamaterial-based FAS

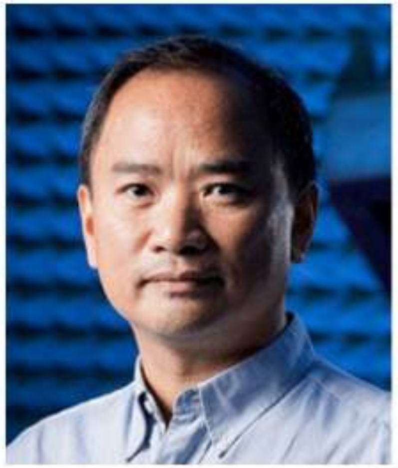
  B. Liu *et al.*, "**Be water, my antennas: Riding on radio wave fluctuation in nature for spatial multiplexing using programmable meta-fluid antenna**," arXiv:2502.04693, Feb. 2025.

Liquid-based FAS

- A piece of liquid metal is encapsulated into a tube which can be shifted within using an electronically controlled pump



Prof. Steve Hang Wong
CityU

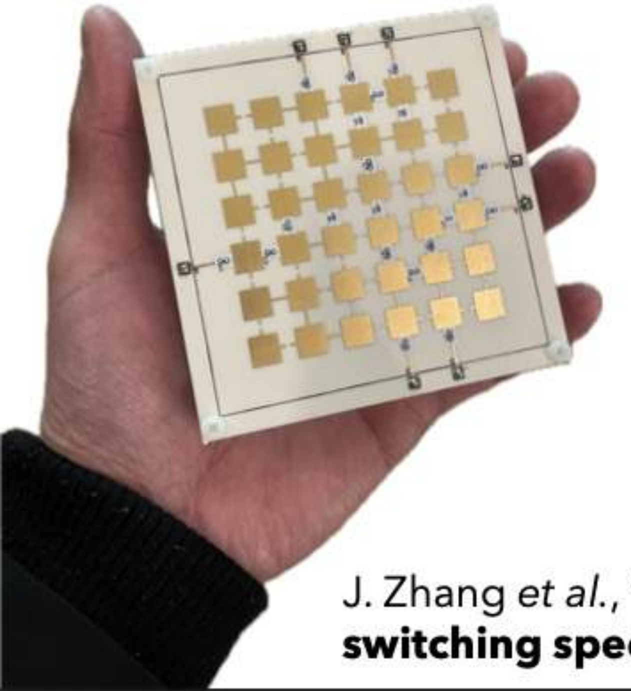


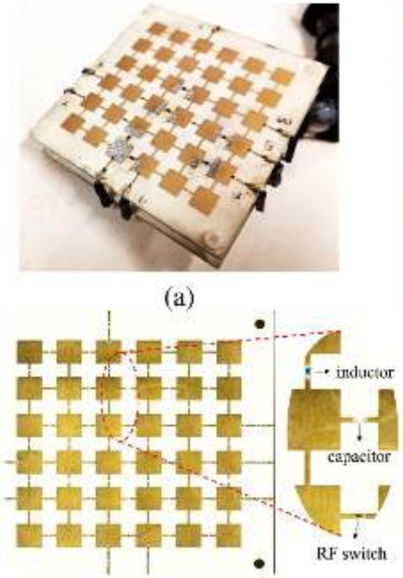
Prof. Kenneth Tong
HKMU

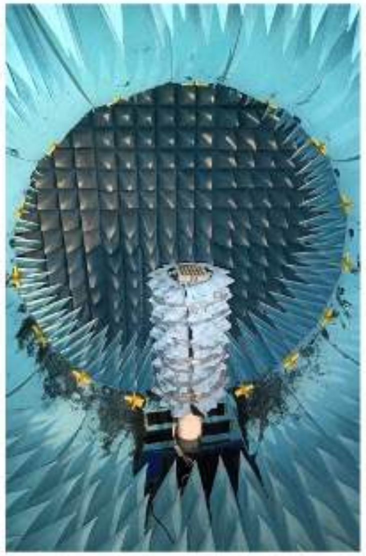
Y. Shen *et al.*, "**Design and implementation of mmWave surface wave enabled fluid antennas and experimental results for fluid antenna multiple access**," [Online] arXiv:2405.09663, May 2024.

Pixel-reconfigurable FAS

- This design is based on a surface of mini pixels that have pre-optimised connections between them





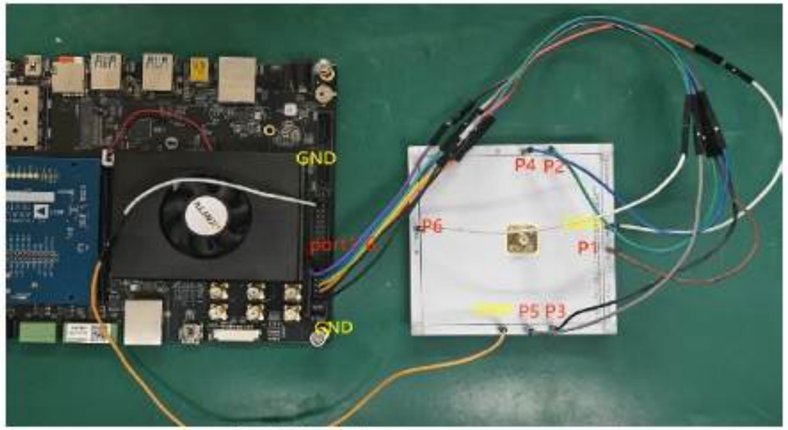


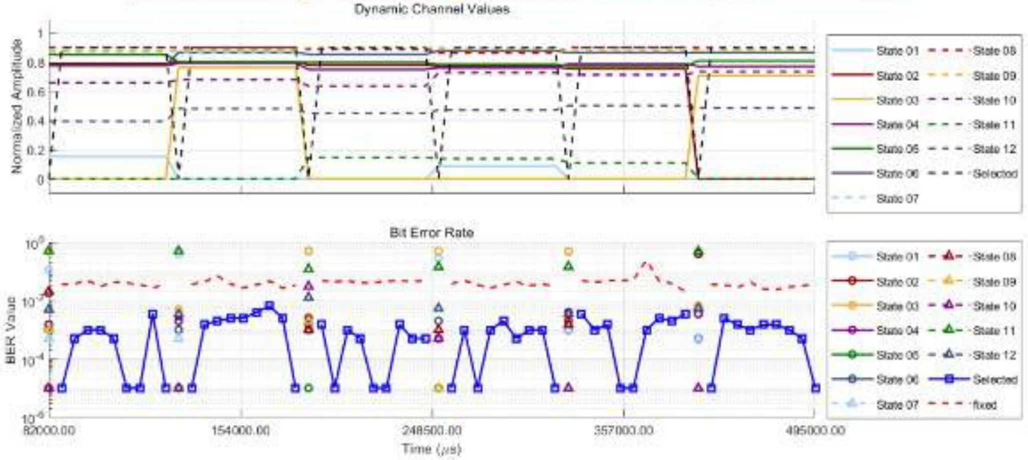
Prof. Ross Murch
HKUST

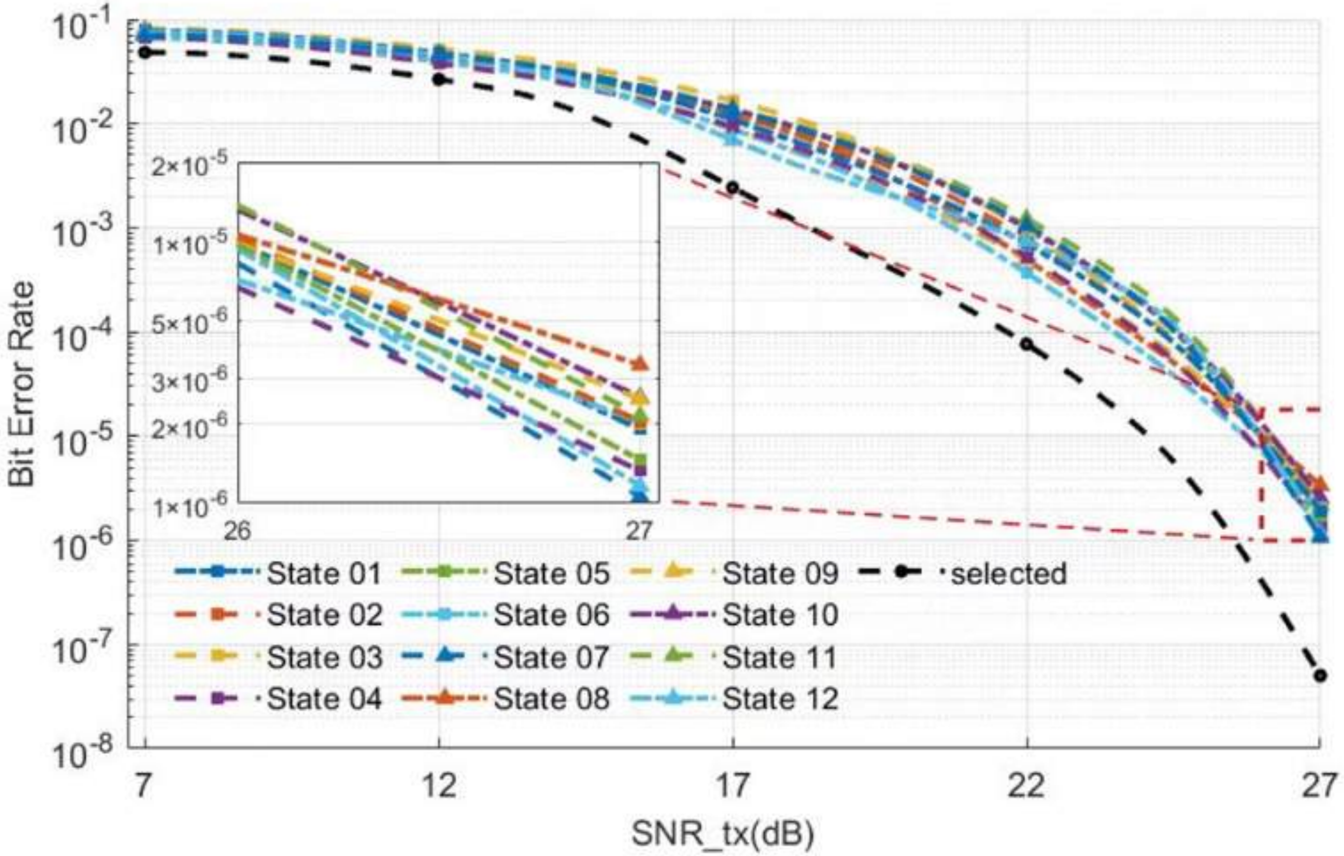
J. Zhang *et al.*, "**A novel pixel-based reconfigurable antenna applied in fluid antenna systems with high switching speed**," IEEE Open Journal of Antennas and Propagation, Vol. 6, No. 1, pp. 212-228, Feb. 2025.

Early Experiments by

Chao Wang
Xidian University

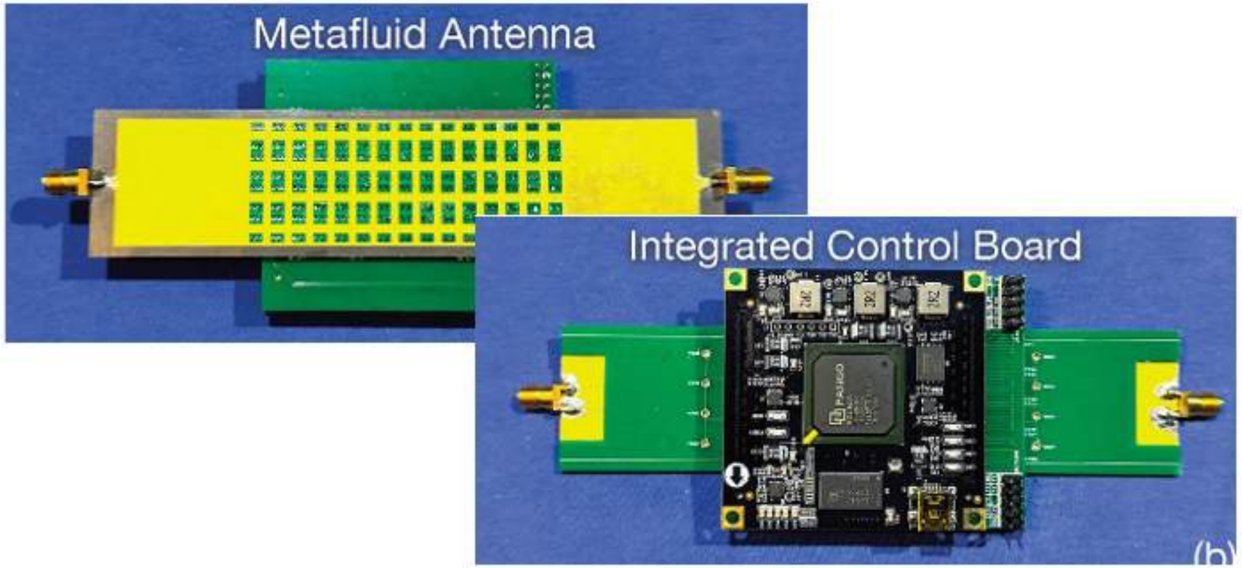






Metamaterial-based FAS

- This design consists of slot-based structures that can be tuned to relocate the antenna aperture of the surface



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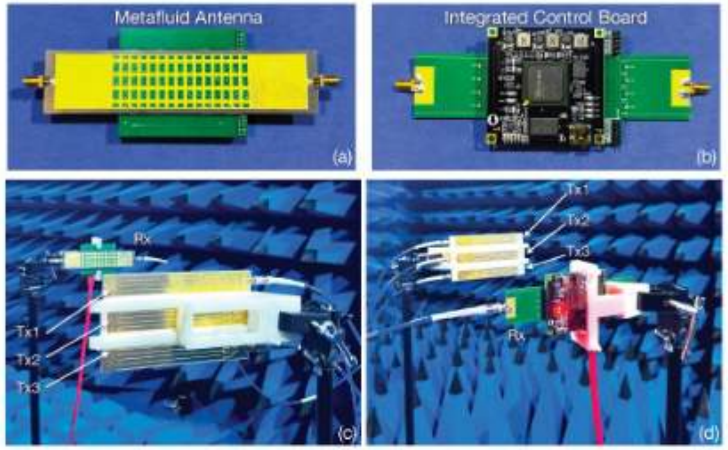
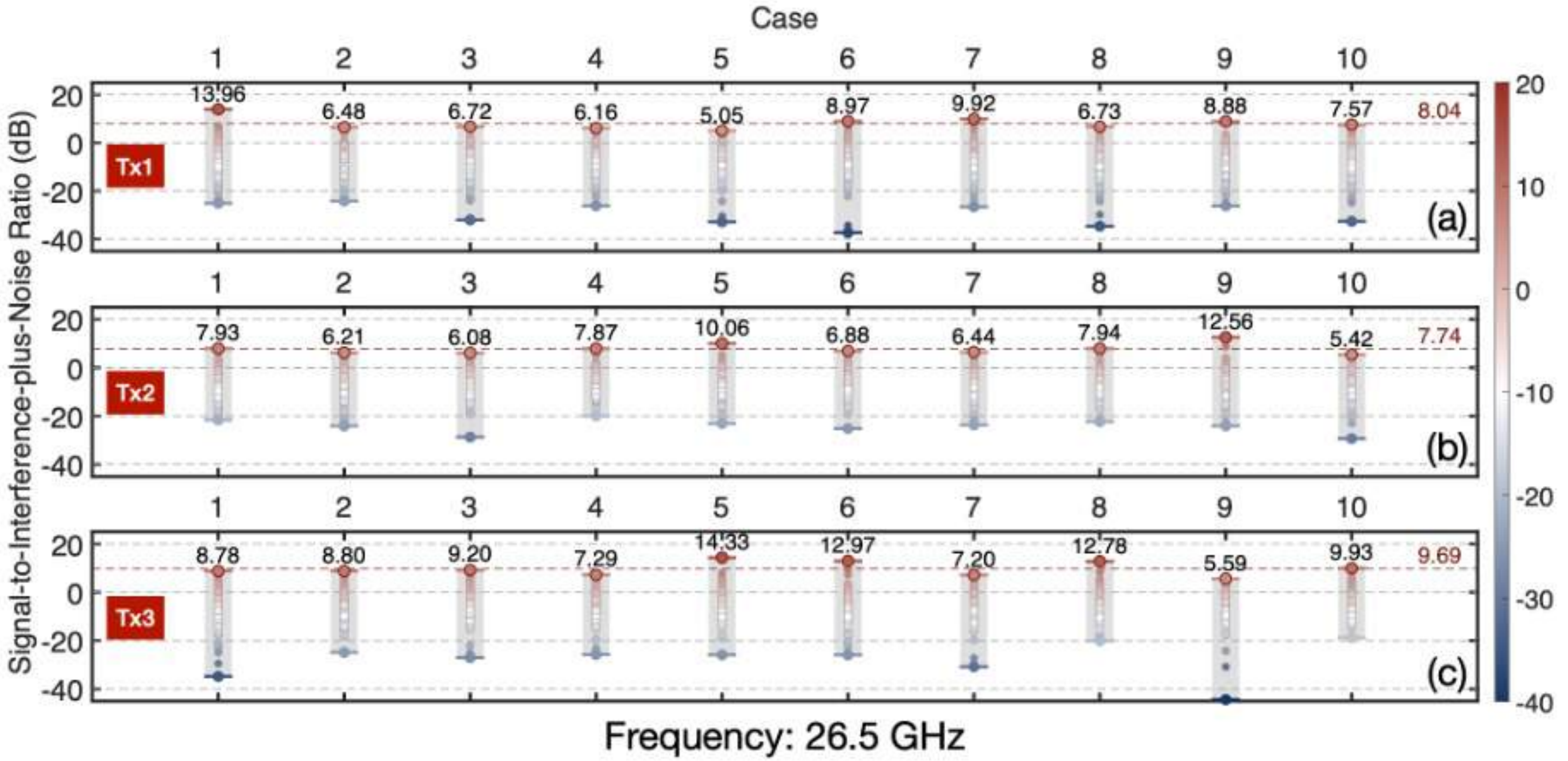
Prof. Steve Wong
CityU

Prof. Kenneth Tong
HKMU

B. Liu *et al.*, "**Be water, my antennas: Riding on radio wave fluctuation in nature for spatial multiplexing using programmable meta-fluid antenna**," arXiv:2502.04693, Feb. 2025.

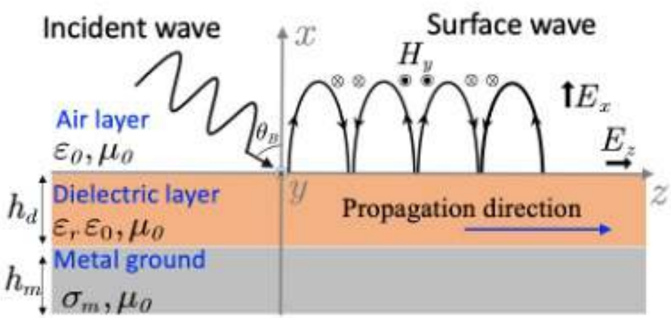
Experimental Results

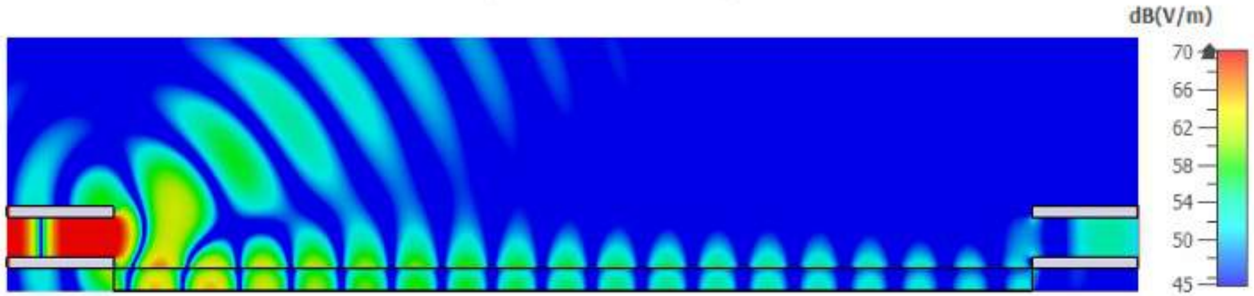


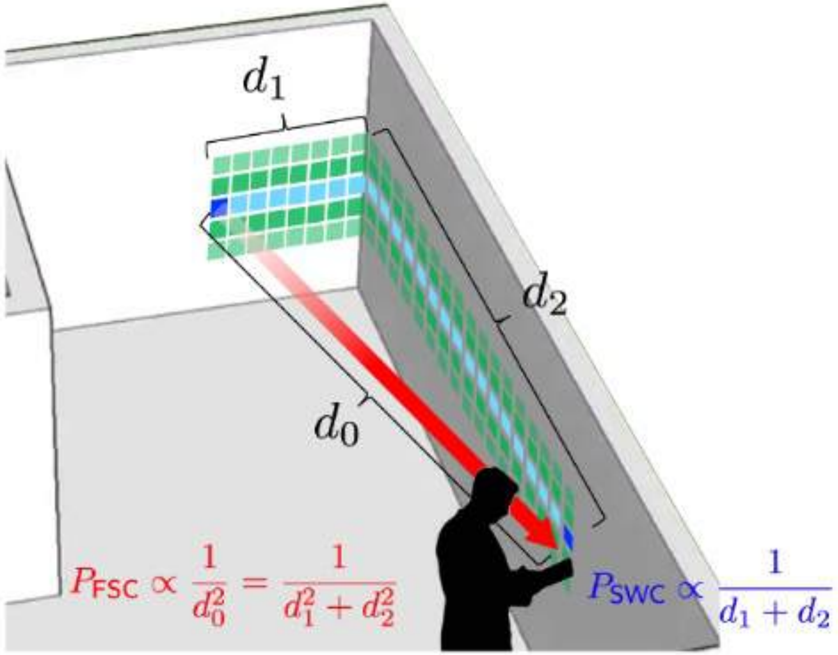


Enormous FAS (E-FAS)

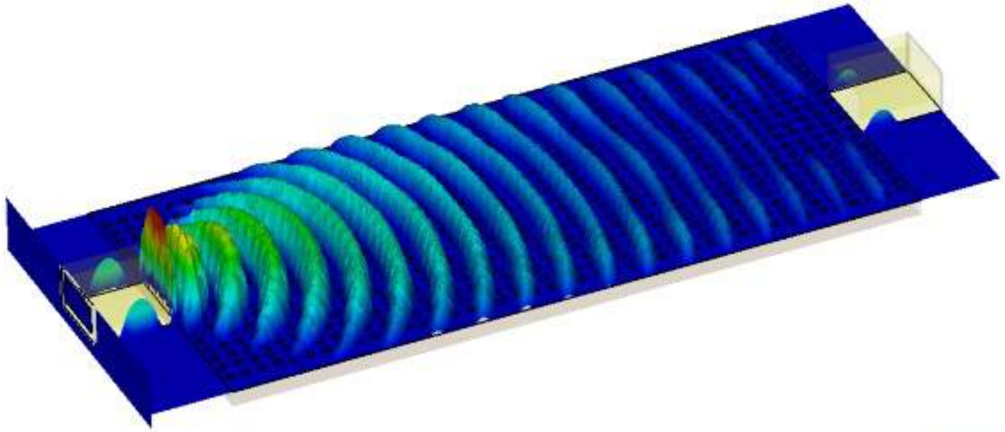
- Surface wave communications
  - Surface wave is a non-radiating wave that propagates along the interface between two homogeneous media such as a dielectric-metal surface
  - More controlled
  - Less interference
  - Less attenuation
  - Higher efficiency

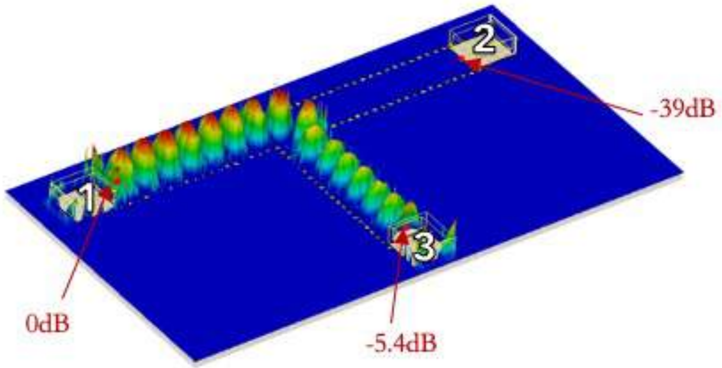


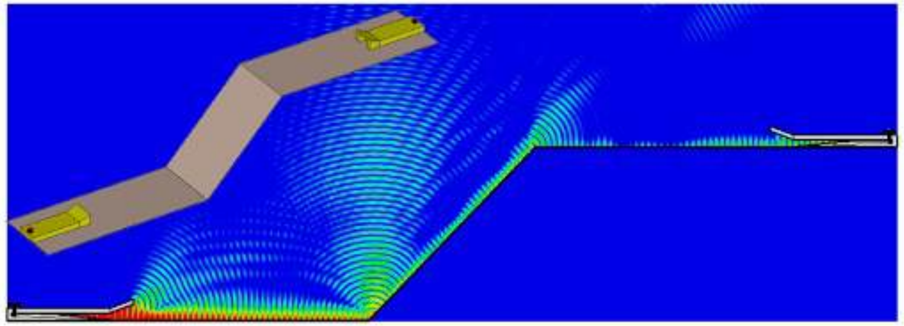


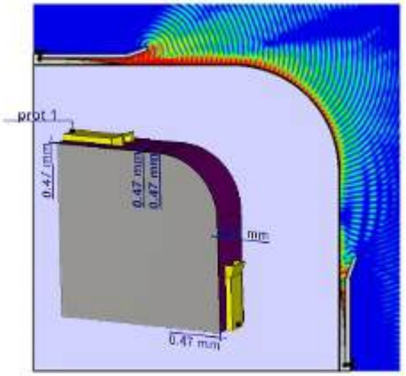


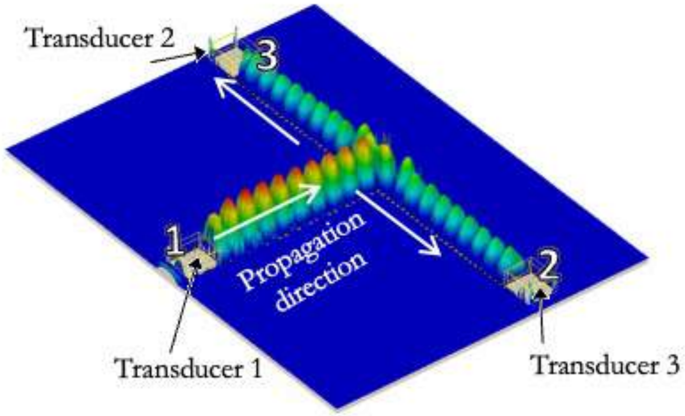
What Reconfigurable SW can Do?

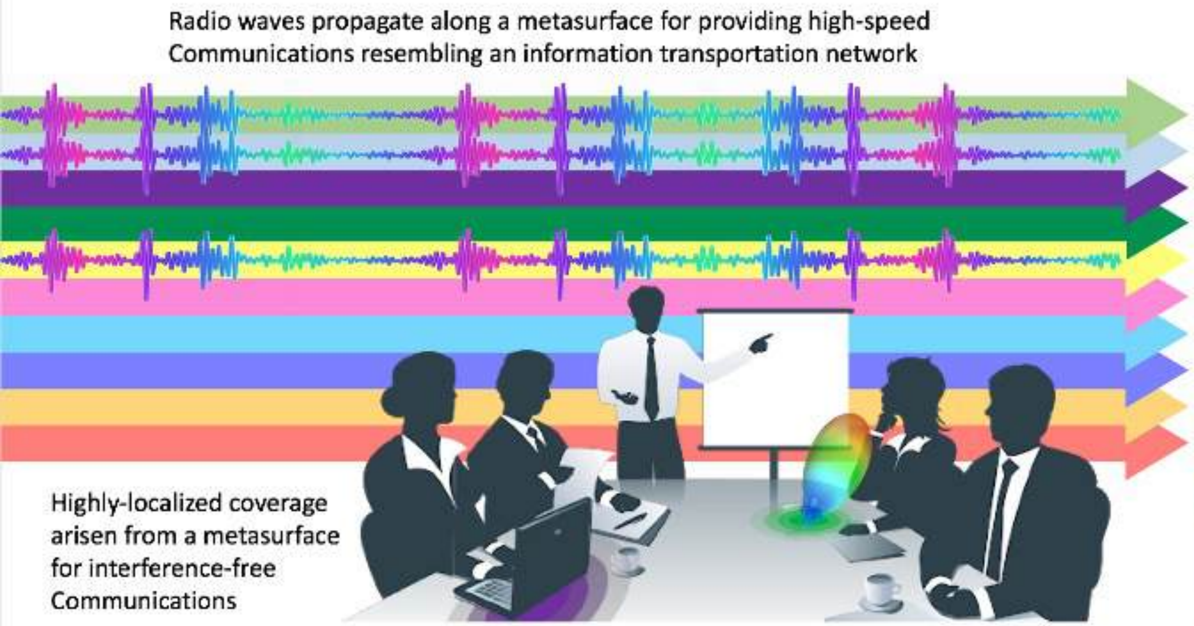








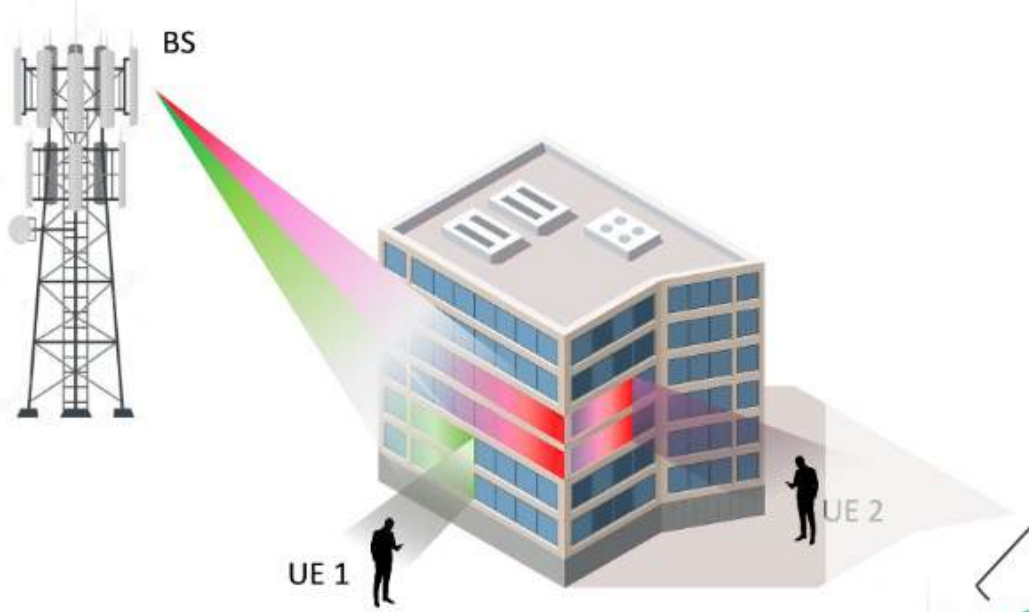


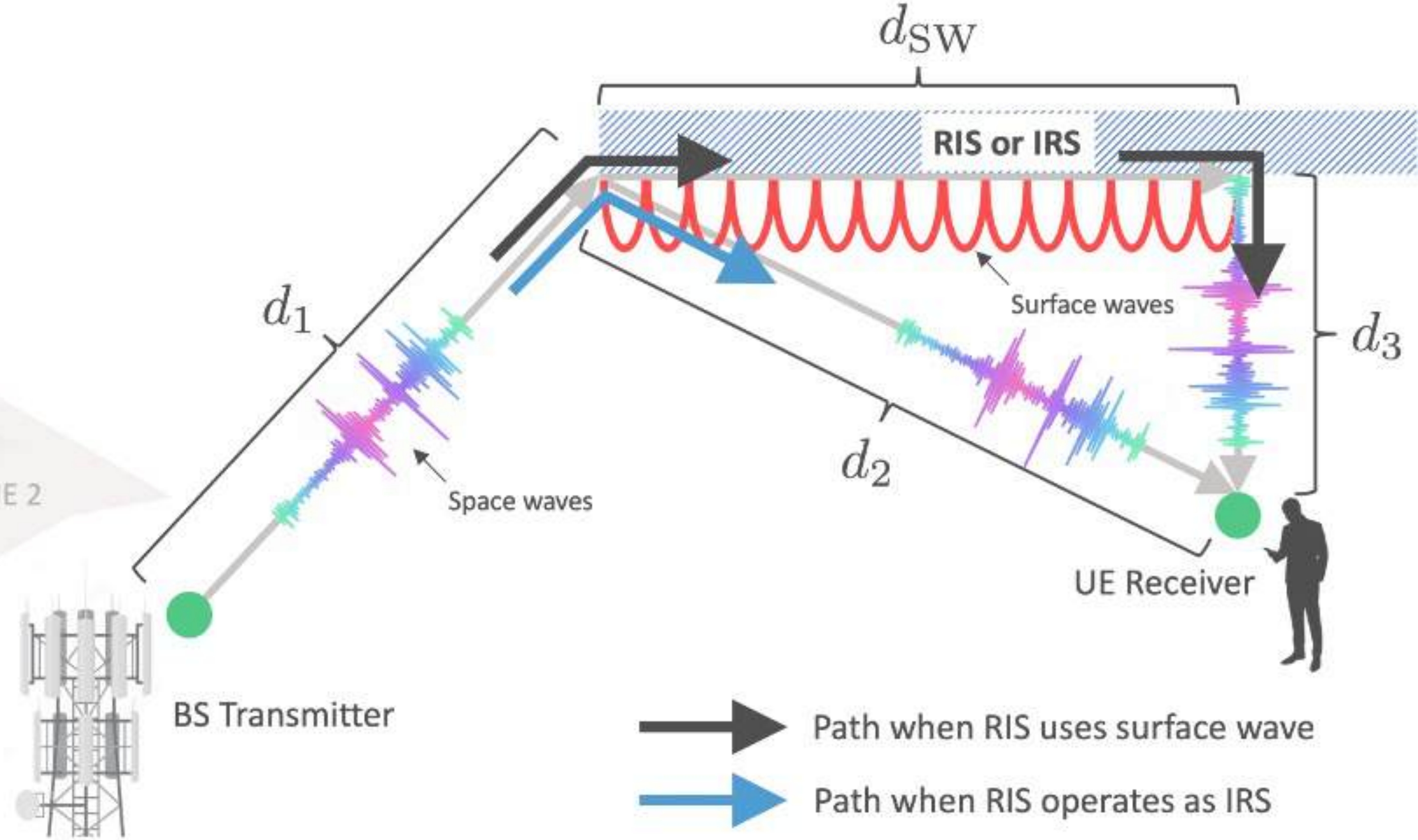


K. K. Wong, K. F. Tong, Z. Chu, and Y. Zhang, "**A vision to smart radio environment: Surface wave communication superhighways**," IEEE Wireless Communications, Vol. 28, No. 1, pp. 112-119, February 2021.

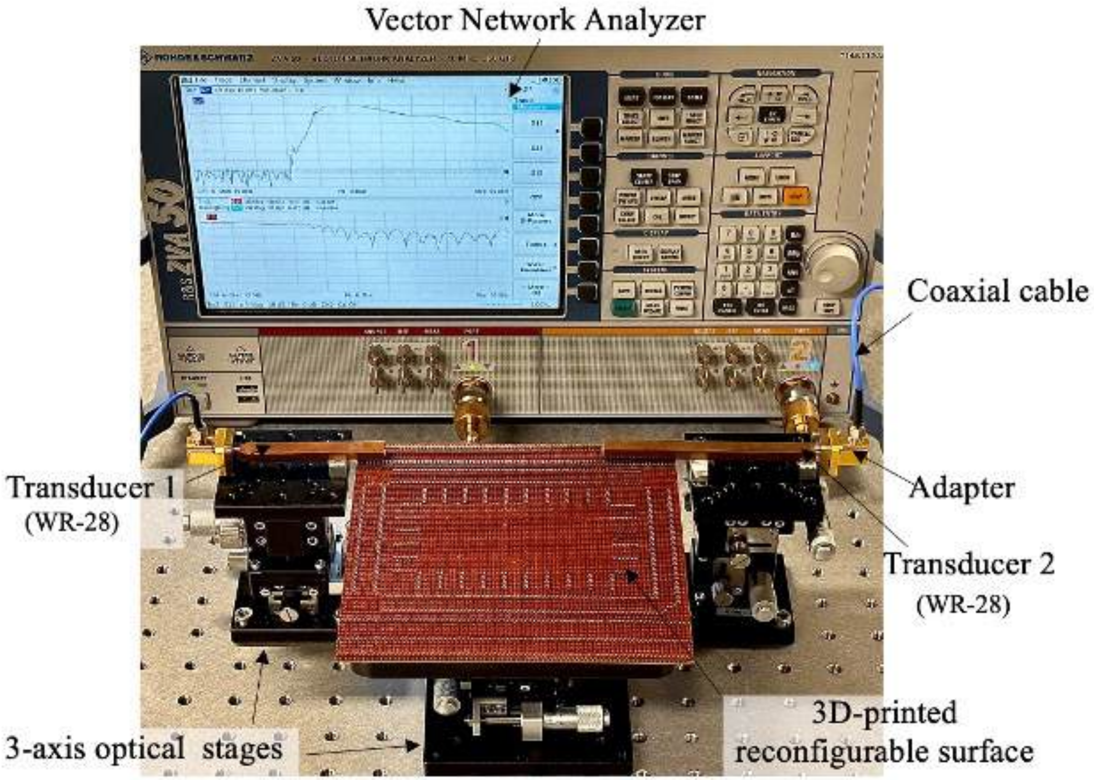
Enormous FAS (E-FAS)

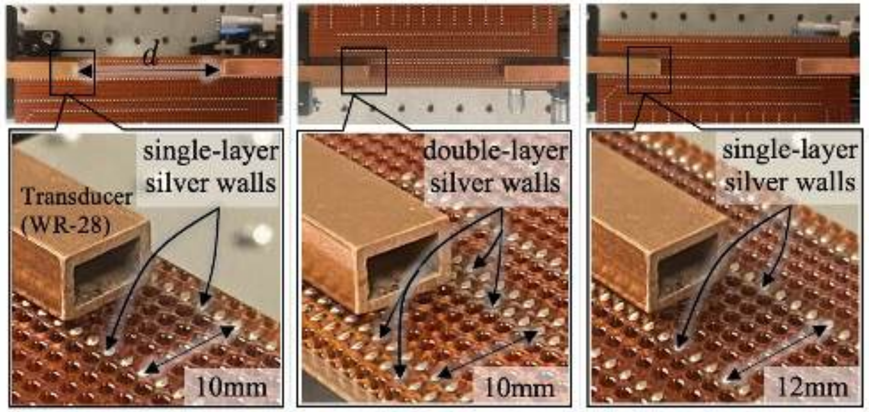
No More Blocking





Reconfigurable Platform Prototype





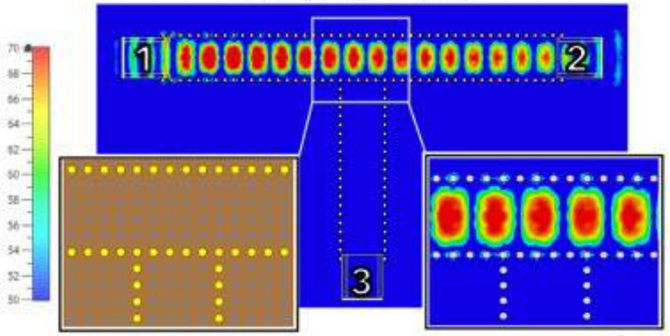
Parameter	Value
transducer (WR-28) frequency band, f_b	$21 - 42$GHz
relative permittivity of the dielectric layer, ε_r	2.8
effective permittivity of the dielectric layer, $\varepsilon_r^{\mathrm{eff}}$	2.4
surface porosity, ρ	19.63%
tangential loss, $tan\delta$	0.0155
channel width, w_c	10mm
thickness of the dielectric layer, h	2mm
thickness of the metal ground, h_m	0.05mm
radius of cavity, r	0.5mm
center-to-center separation between cavity, w_s	2mm
electrical conductivity of silver ink, σ_s	3.15×10^6 S/m
surface impedance, Z_s	$j240\Omega$ at 26GHz

Dielectric resin ink

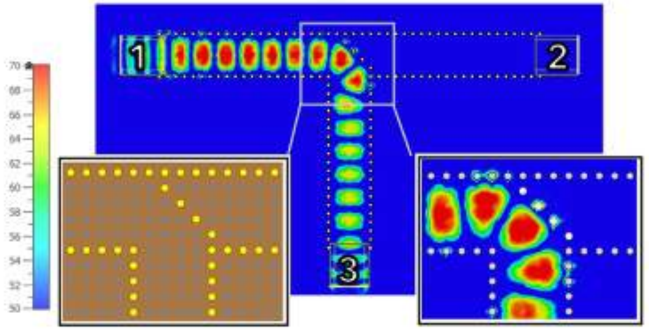
Silver ink

Experimental Results

Straight pathway



Turn pathway



1. Z. Chu, W. K. New, K. F. Tong, K. K. Wong, H. Liu, C.-B. Chae, and Y. Zhang, "**On propagation loss for reconfigurable surface wave communications**," IEEE Transactions on Communications, vol. 73, no. 3, pp. 1547–1559, March 2025.
2. Z. Chu, K. F. Tong, K. K. Wong, C.-B. Chae, and C. H. Chan, "**On propagation characteristics of reconfigurable surface wave platform: Simulation and experimental verification**," IEEE Access, vol. 12, pp. 168744-168754, November 2024.
3. H. Liu, W. K. New, H. Xu, Z. Chu, K.-F. Tong, K. K. Wong, and Y. Zhang, "**Path loss and surface impedance models for surface wave-assisted wireless communication system**," IEEE Access, vol. 12, pp. 125786-125799, August 2024.
4. K. K. Wong, K. F. Tong, Z. Chu, and Y. Zhang, "**A vision to smart radio environment: Surface wave communication superhighways**," IEEE Wireless Communications, vol. 28, no. 1, pp. 112-119, February 2021.

Upcoming Activities on FAS

Workshops

- IEEE/CIC ICCC in Shanghai, China (August 2025)
- IEEE GLOBECOM in Taipei, Taiwan (December 2025)

Tutorial

- IEEE GLOBECOM in Taipei, Taiwan (December 2025)

Demo

- IEEE/CIC ICCC in Shanghai, China (August 2025)

Special issues

- IEEE JSTSP (15-Aug-25), FCN (29-Aug-25), TCCN (30-Oct-25), … etc.

A **WeChat Group** for the FAS community:

Conclusion

- A **webpage** on the ComSoc TCCN website

☞ https://sites.google.com/view/ieee-comsoc-tccn-sig-fas/Home

- A **webpage** on the ComSoc WTC website

☞ https://sites.google.com/view/wtc-sig-fas/home

- A **website** for both SIGs on FAS

☞ https://www.fas.academy

- A **YouTube channel** for FAS

☞ https://www.youtube.com/@FluidAntennaSystem