Compact User Antennas for UAV-NTN in Space-Air-Ground (3D) Integrated Networks

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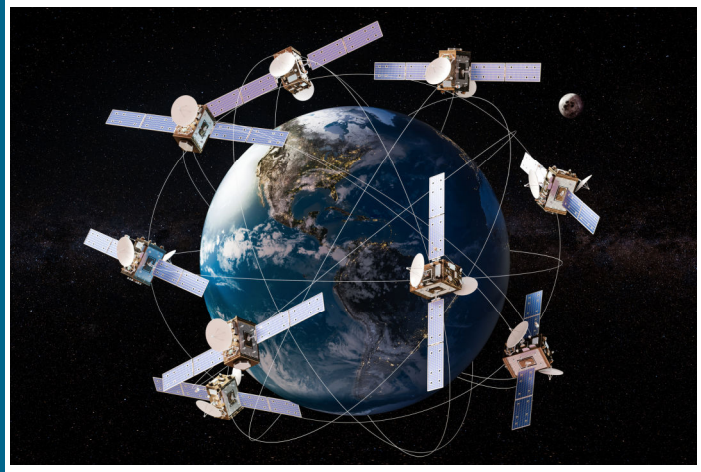
DLR

Outline

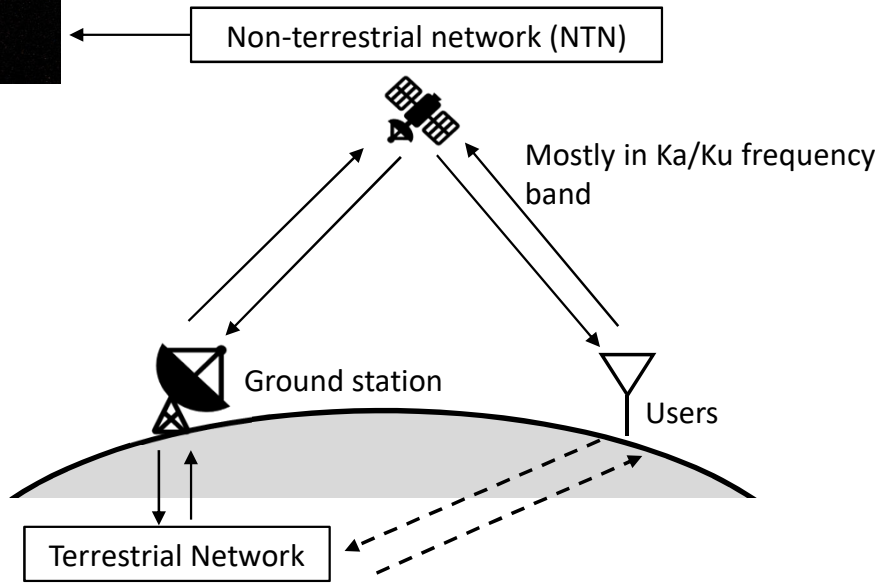
- NTN Overview.
- User Platforms: Stationary and Mobile.
- Antenna: Small footprint.
- Antenna: SWaP-C reduction.
- Current developments at DLR.
- Conclusion

NTN Overview

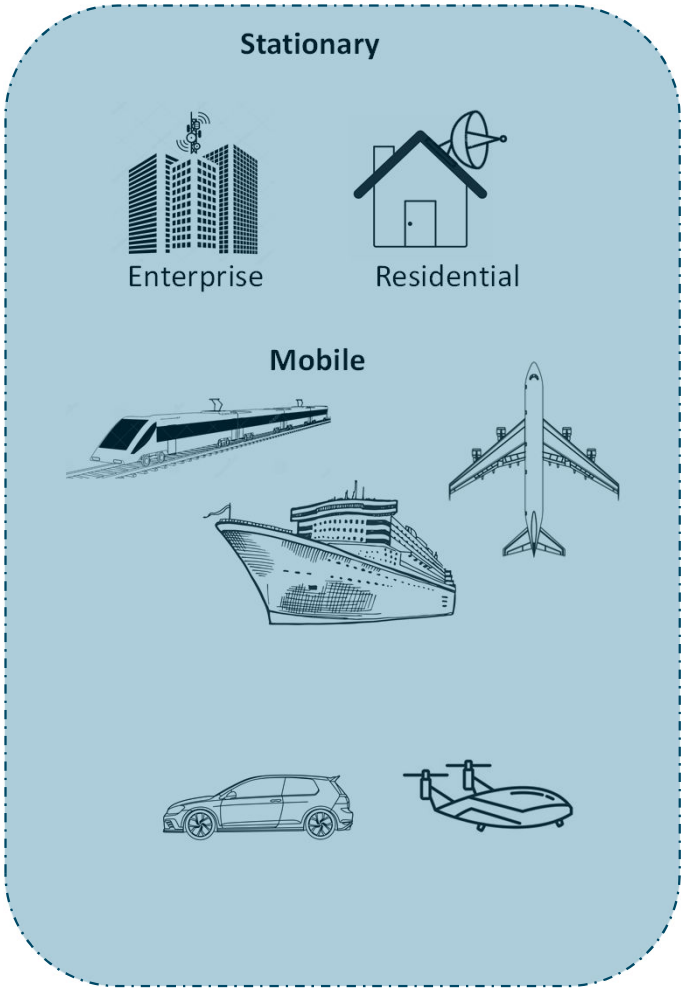


TN-NTN Integration:

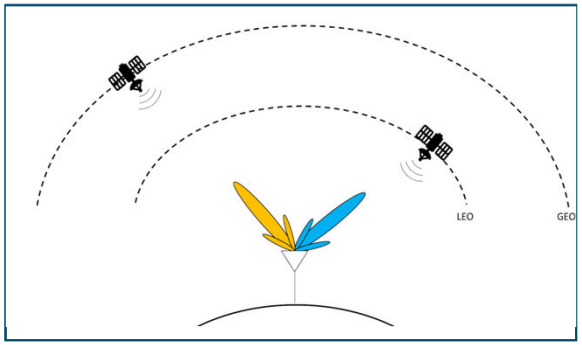
- Unavailability of TN in remote areas.
- Destruction of TN networks by natural/man-made disasters.
- Sharing user traffic between TN and NTN.



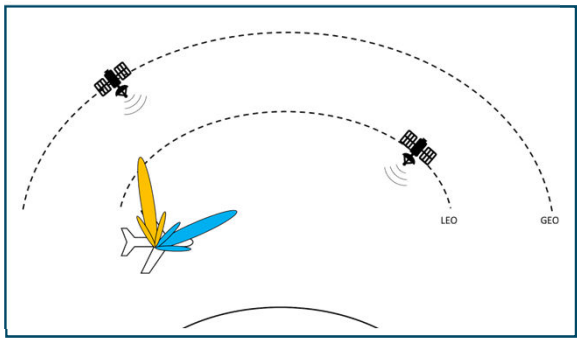
User Platforms



Orbital altitude*
VLEO : < 300 km
LEO : 300-1500 km
MEO : 7000-25000 km
GEO : 35786 km



Stationary user

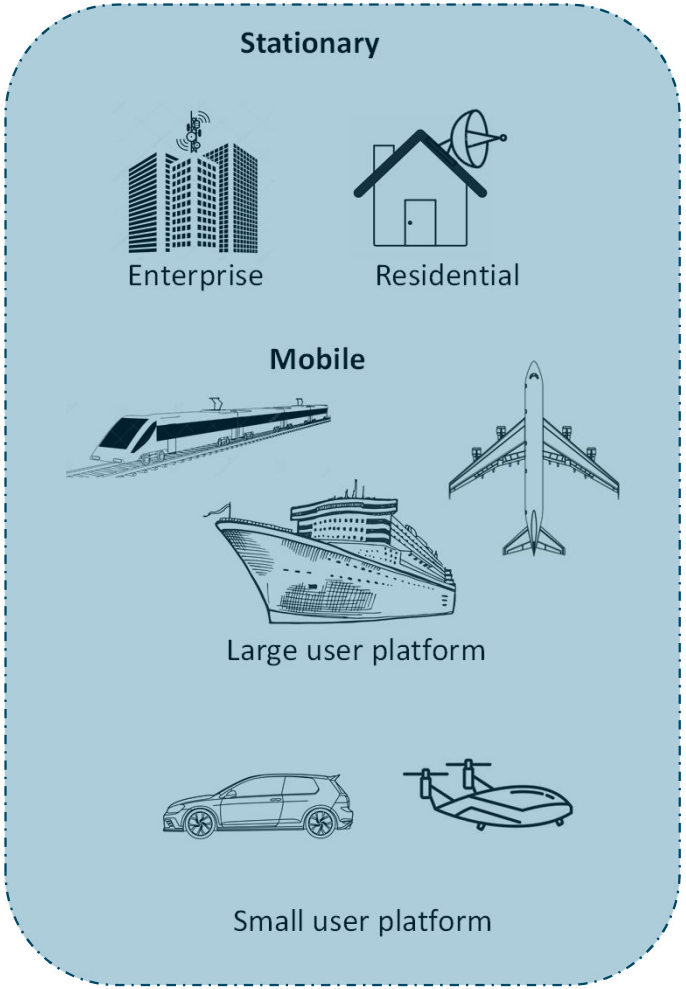


Mobile user

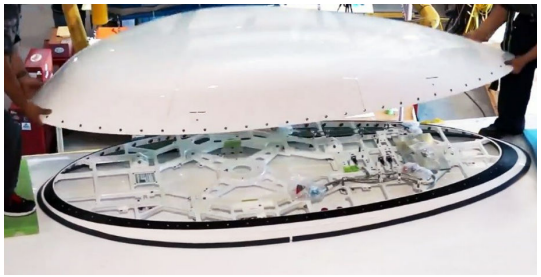
Steerable/reconfigurable antennas are essential.

* 3GPP, *Solutions for NR to support non-terrestrial networks (NTN)*, document TR 38.821 V16.2.0, Mar 2023.

User Platforms - Mobile



Large user platforms



- More flexibility in user terminal design.
- More freedom in SWaP-C (Size, Power, Weight, Cost).
- Vast variety of technology and commercial terminals available.

Small user platforms

- **Small user terminal antennas are essential.**
- **Low SWaP-C expected.**

Antenna → Small footprint

PLANET 9770 UAV-L *
- Antenna: 134g, 3.8cm height, 8 cm diameter.
- Iridium Certus™ 100 satellite service.
- L band.
- 88 Kbps DL.

More throughput with Ka band?

Comparable footprint?

- Ka band RX (20GHz)
- 64 elements

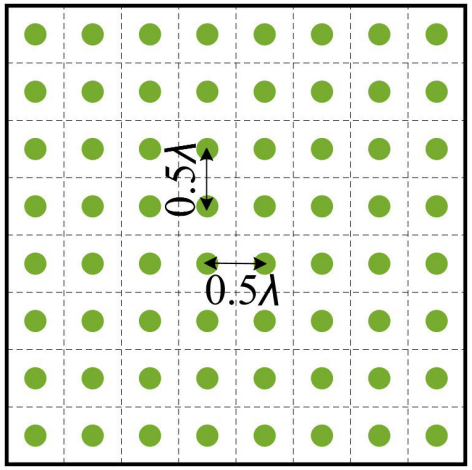
~6 cm

~6 cm

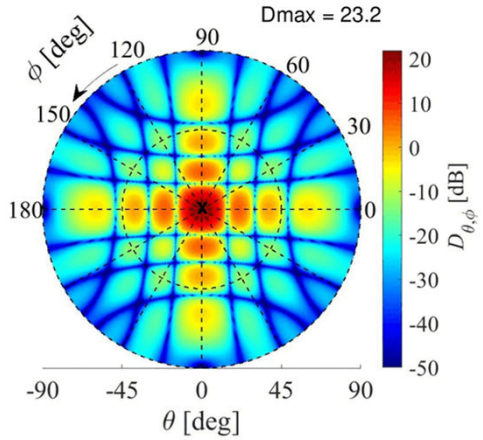
*PLANET_9770_UAV-L_Terminal_V1-0.pdf (atmosphere.aero)

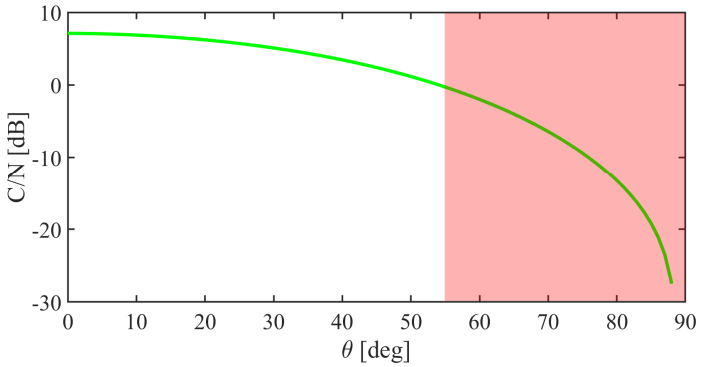
Antenna → Small footprint

~6 cm



Ideal max gain	~ 23dBi
C/N (LEO)	~ 7dB
Datarate	~ 11 Mbps In 5MHz bandwidth using DVB S2X modem

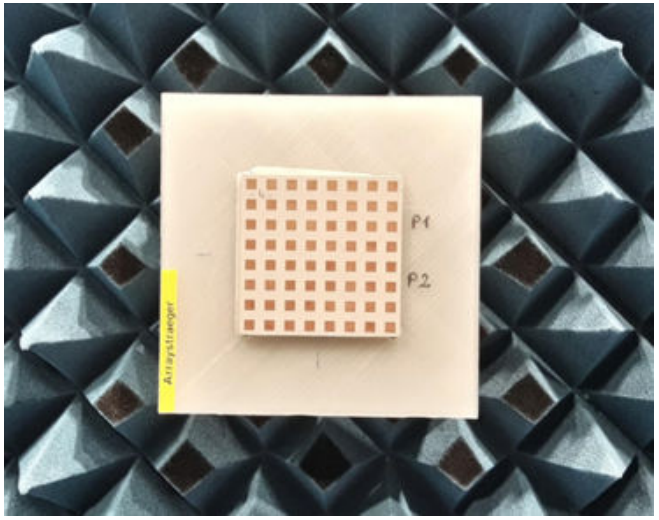


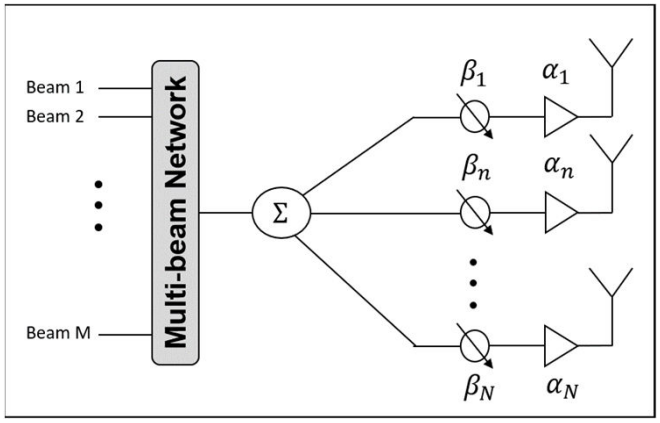


Small arrays are capable for NTN applications (acceptable gain in analyzed steering cases till 55°).

Antenna → SWaP-C reduction

- Reconfigurability
- Electronic steering
- Compact
- Power consumption
- Cost

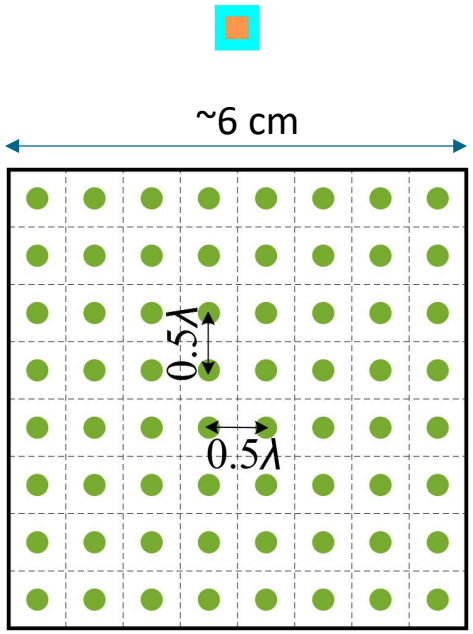




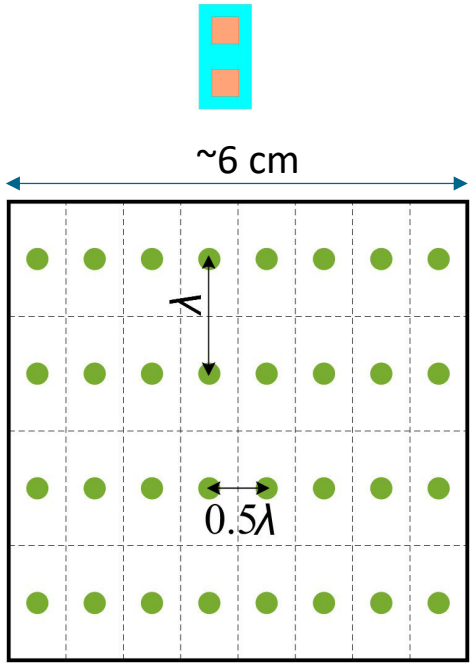
Clustering

→ Antenna elements have a common excitation (amplitude/phase) control point resulting in less price and power consumption.

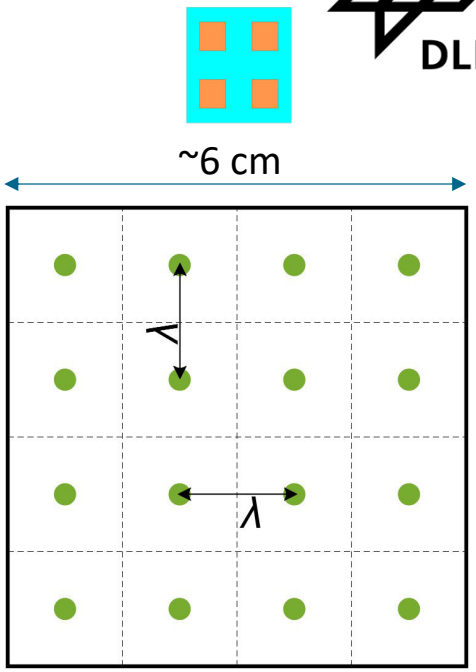
Clustering*



Array1: No clustering



Array2: 2-element cluster



Array3: 4-element cluster

If one beamformer IC supports 4 dual-polarized elements:

ICs required: 16

ICs required: 8

ICs required: 4

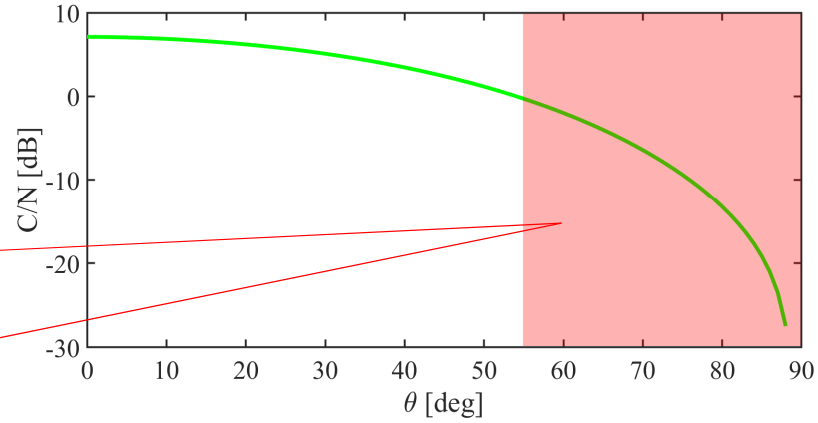
*A.P.T. Adithyababu, F. Boulos, and S. Caizzone, ”Analysis of performance and radiation regulation compliance on a miniature Ka band antenna”, in IEEE International Symposium on Antennas and Propagation and ITNC-USNC-URSI Radio Science Meeting, Florence, Italy, 2024 (submitted).

Analysis*

- Small footprint and clustering: Degradation of performance (and occurence of grating lobes) as expected.
- Analysis→ Find the trade-off between the performance degradation and SWaP-C reduction.

Performance exhibited by 3 analyzed arrays*

(θ°,Φ°)	Dmax		
	A1	A2	A3
0,0	23.2	22.8	23.2
30,0	22.3	22.1	19.6
60,0	18.7	18.8	8.1
30,45	22.4	20.8	20.1
60,45	19.4	15.1	11.0



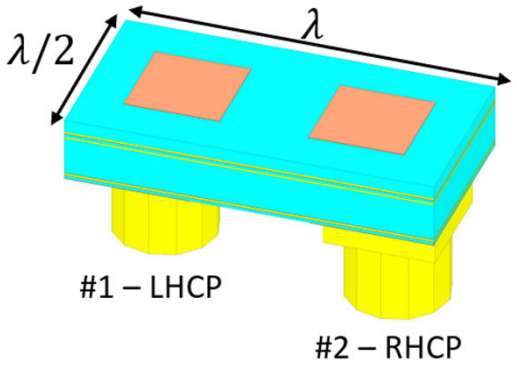
SWaP-C reduction:
- 4 element clustering shows major reduction in gain which makes it impossible to close the link.
- 2-element clustering found to be a good trade-off (acceptable and comparable performance to A1 in most cases).

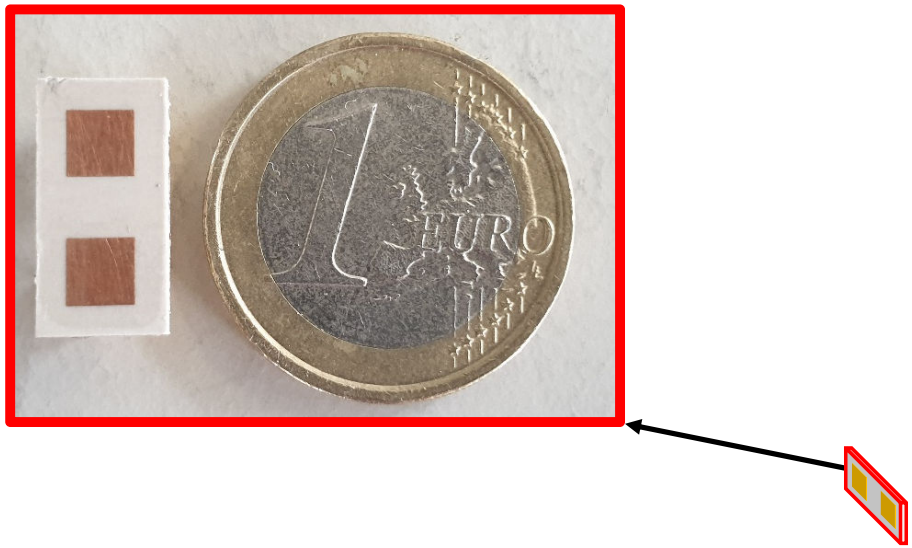
*A.P.T. Adithyababu, F. Boulos, and S. Caizzone, ”Analysis of performance and radiation regulation compliance on a miniature Ka band antenna”, in IEEE International Symposium on Antennas and Propagation and ITNC-USNC-URSI Radio Science Meeting, Florence, Italy, 2024 (submitted).

Antenna element developed at DLR

Antenna (domino)*:

- 2-element cluster
- Ka-band RX (19.7-20.2 GHz)
- Simultaneous Dual CP (LHCP, RHCP)



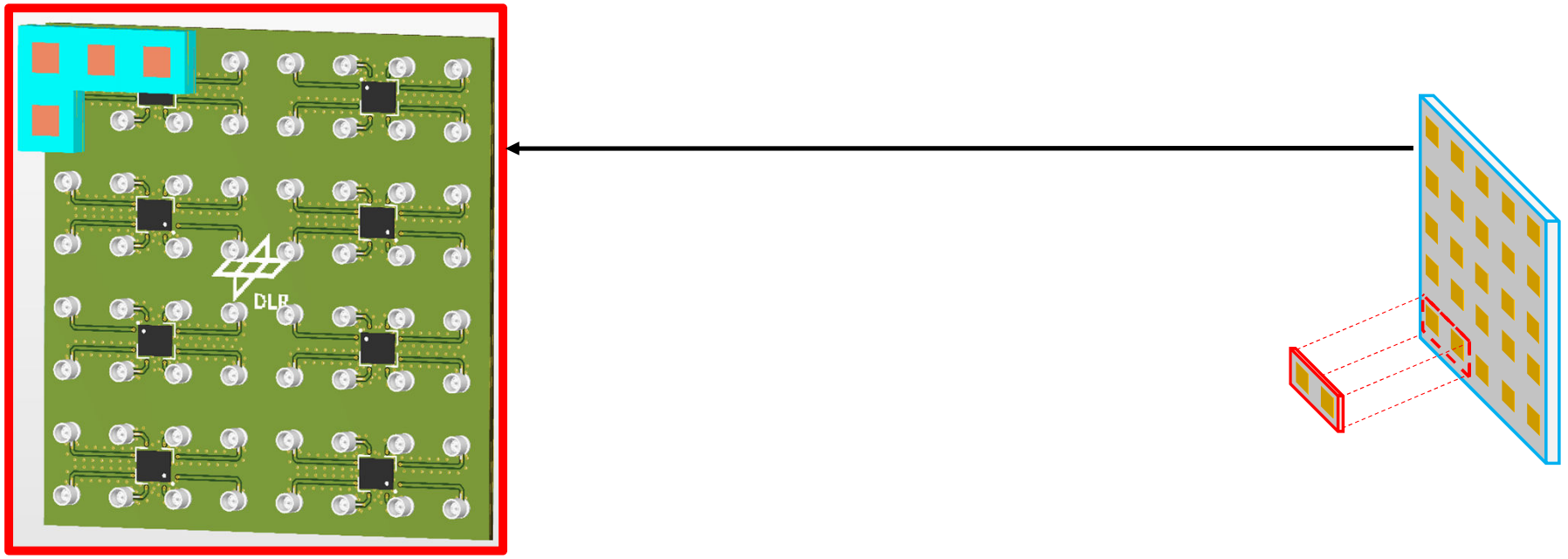


*F. Boulos, U. Johannsen, and S. Caizzone, "Customizable phased array antenna based on domino tiles for satcom applications," in IEEE International Symposium on Phased Array Systems and Technology, Waltham, Massachusetts, USA, 11-14 Oct. 2022.

Beam-former Board Developed at DLR

Beam-former board*:

- Using Anokiwave AWMF 0197 IC
- Board dimension ~6 cm
- Support different orientations of dominos.



*F. Boulos, E.O. Addo, S. Caizzone, and U. Johannsen, “A Modular, Low-cost Ka band Antenna Subarray as Building Block for Phased Arrays of Arbitrary Size and Shape,” in 18th European Conference on Antennas and Propagation (EuCAP), 2024 (submitted).

Conclusion

- 64 element antenna array being developed→ for small platforms.
- We can make it fly!☺

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