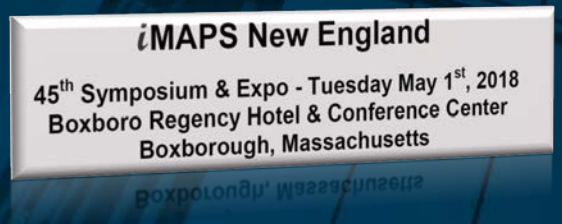
# 5G….The Road Ahead

*Thomas Cameron, PhD*






ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

# 2023

# >1B 5G SUBSCRIBERS

"Ericsson Mobility Report November 2017"

# 5G: A Flexible Network for the Future

10 Tbps/km$^2$

10 Gbps peak

500 km/h Mobility

100 Mbps everywhere


$10^7$ Devices/km$^2$

10 year battery

10X Energy Efficiency




>99.999% Reliable

1ms Latency





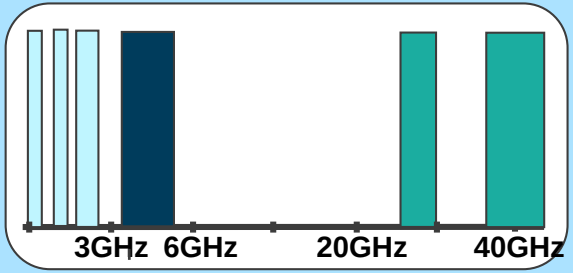
ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

# 5G Radio Toolbox

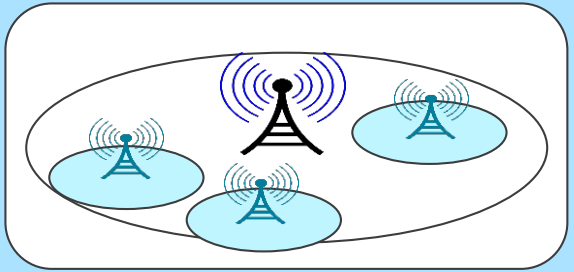
**Capacity (b/s/area) = B X N X η**

B = available bandwidth  N = number of cells/area  η = spectral efficiency

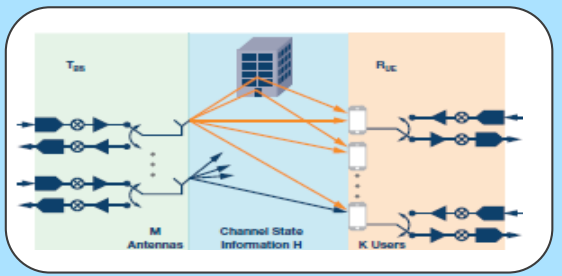
## C-band + mmwave




## Small Cells



## Massive MIMO








ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

# 5G Radio Key Technologies

## Sub 6GHz Massive MIMO

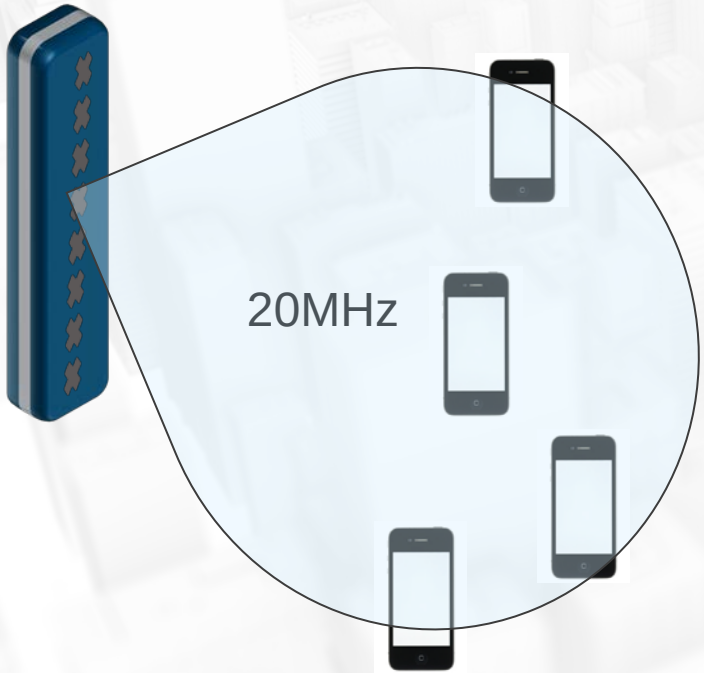
- **Digital beamforming**
- **Technology evolution from current BTS but new challenges**
  - **Many PAs and filters**
  - **Complex interfaces**

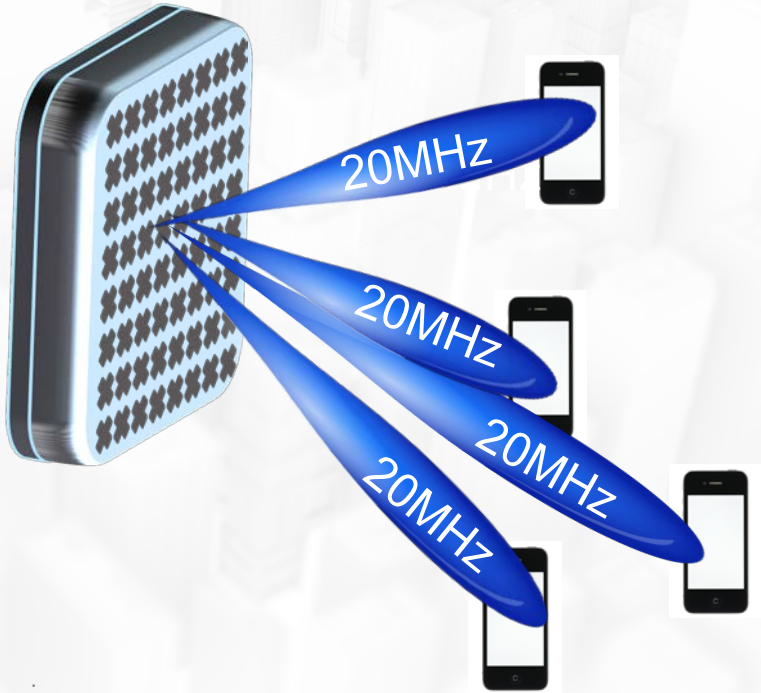
## mmwave Beamforming

- **Hybrid beamforming**
- **Evolve from discrete solutions to very high levels of RF integration**
- **GaAS ➔ Silicon**
- **MCM ➔ Monolithic**

# Massive MIMO

- Spectral efficiency gains through microscopic frequency re-use
- Enabled by M>>K (where M is # antennae and K is number of users)



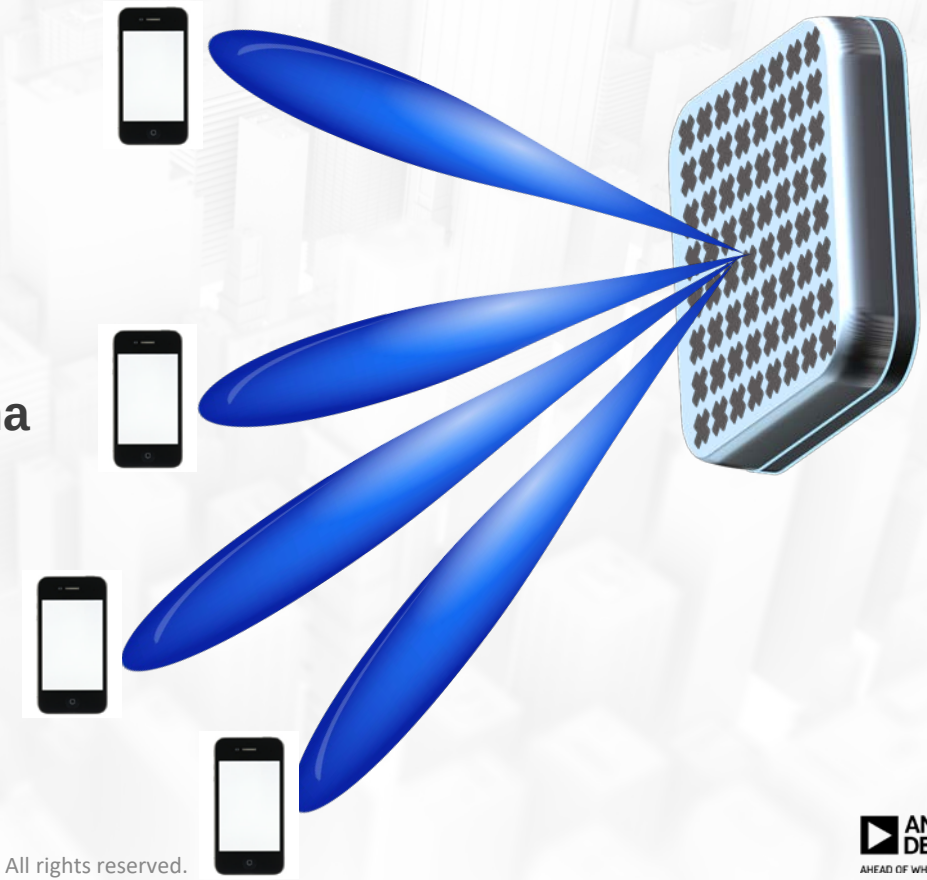





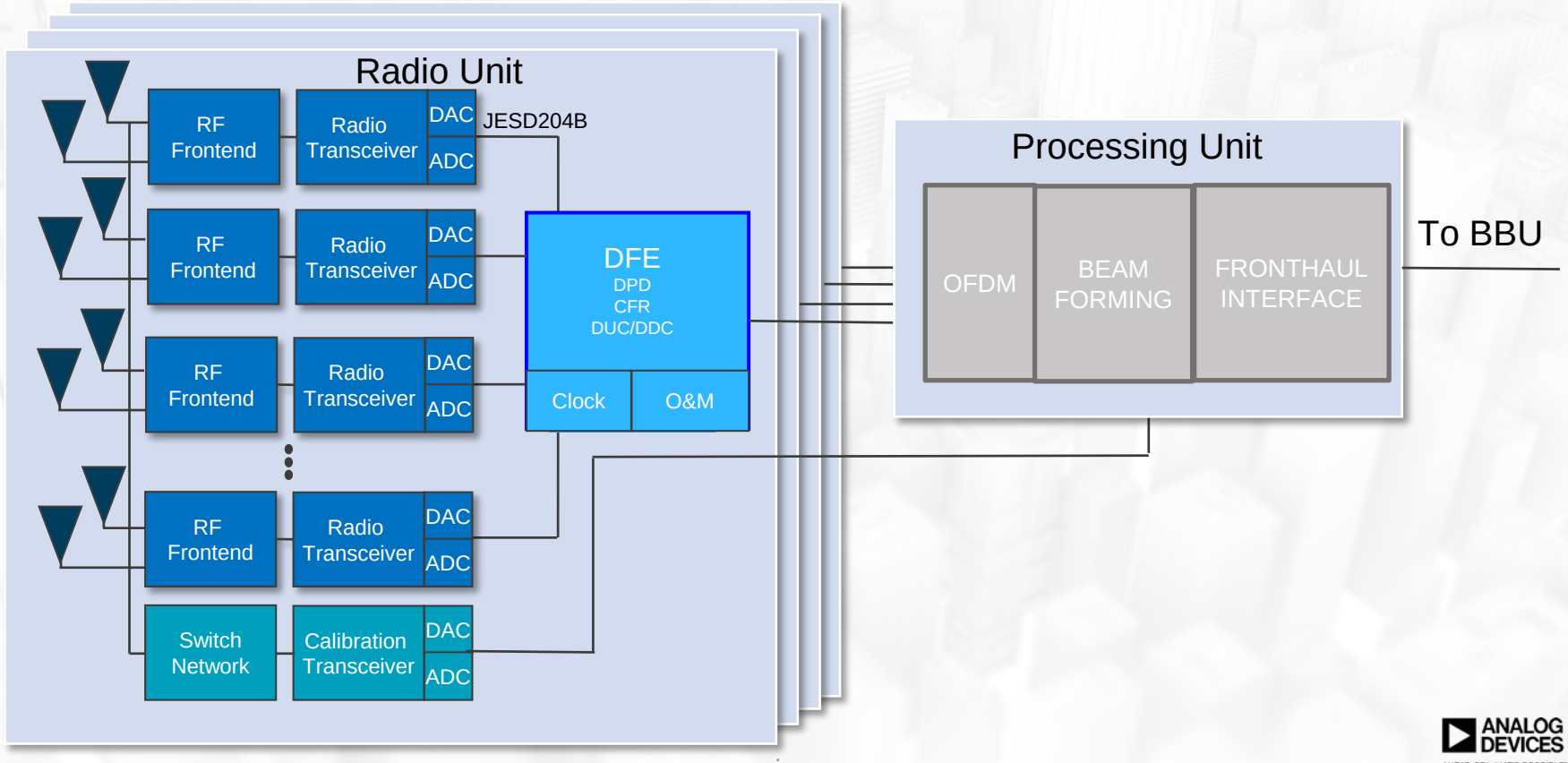

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

# Sub 6GHz Massive MIMO (FD-MIMO)

- **Challenges**
  - **Size**
  - **Weight**
  - **Power Consumption**
  - **Cost**
  - **Complex interface within antenna**
  - **Fronthaul**



# Sub 6GHz – Massive MIMO System

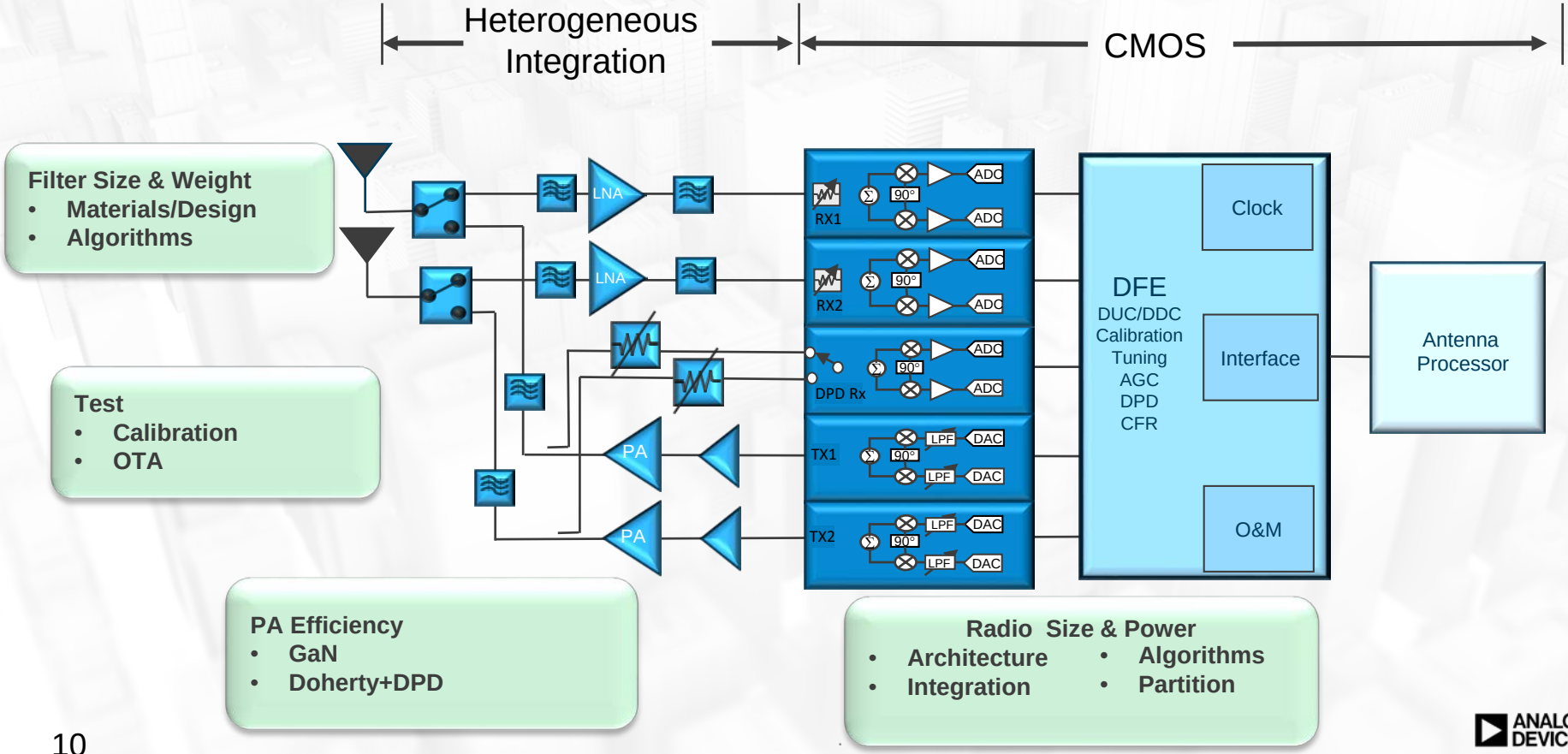







ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

# Sub 6GHz Massive MIMO Radio – Areas for Innovation



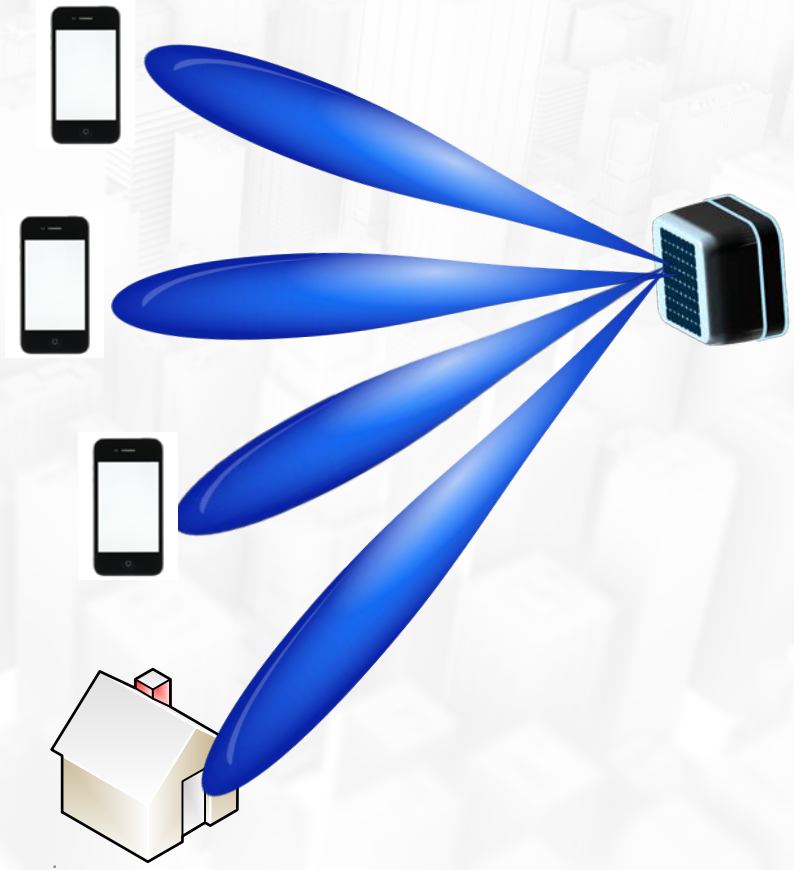





ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

# mmwave 5G

- **Challenges**
  - **Channel model**
    - **Fading**
    - **Blockage**
  - **Beam acquisition and tracking**
  - **Very wide bandwidth**
  - **Power Consumption**
  - **Cost**



# mmwave 5G– Challenges for the Designer

Beamforming Architecture

Broadband Data Conversion

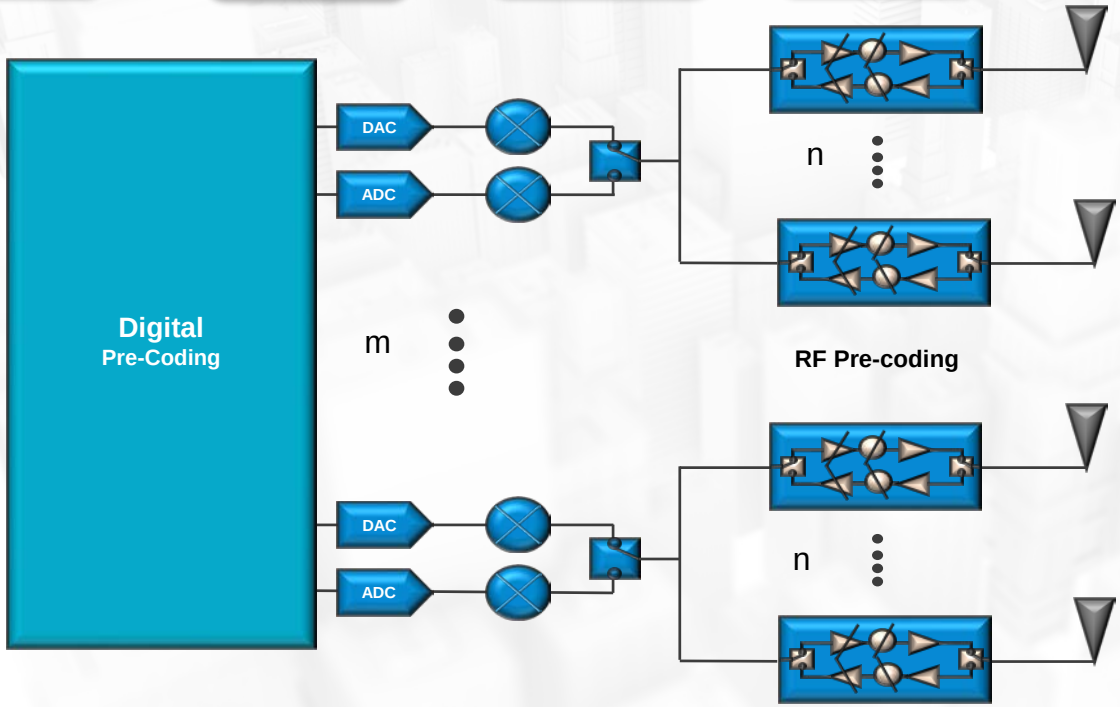
High Performance Frequency Conversion

Efficient Power Generation

Advanced Packaging

OTA Testing

Calibration



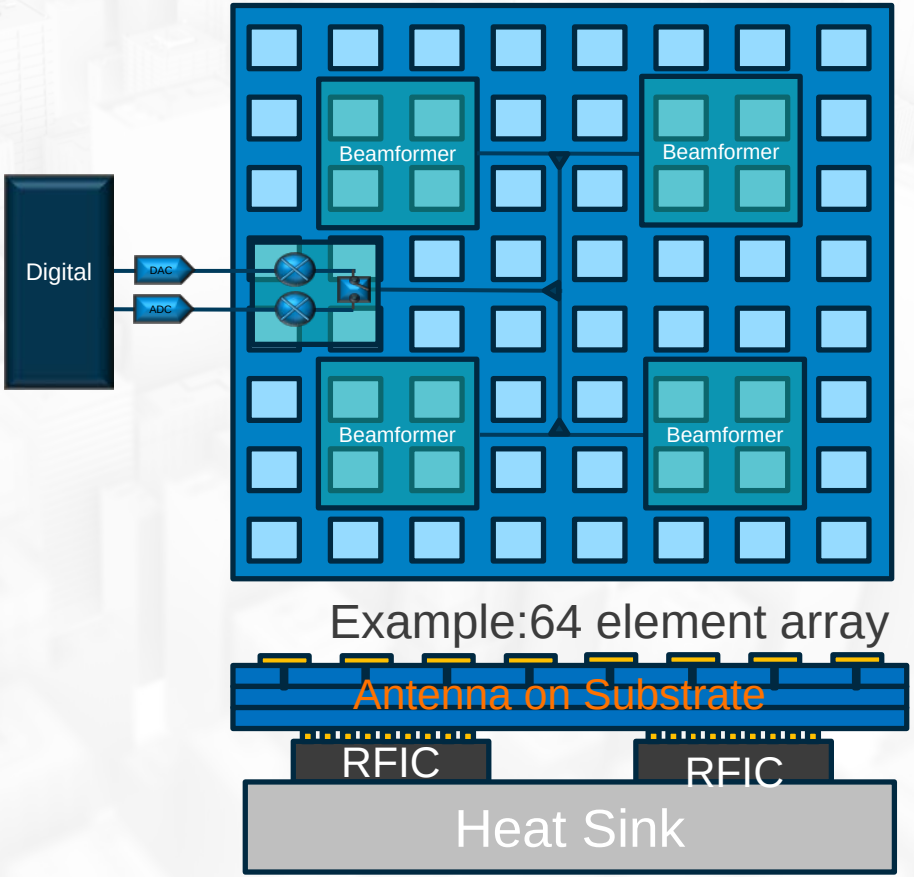





ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

# Example: High Integration Beamformer Assembly

- Compact implementation
- Supports wide range of beamforming in both vertical and horizontal
- Scalable for higher EIRP
- Thermal challenges
- Difficult to implement front end filters
- OTA Test




CONCEPT TO CREATION AT LIGHT SPEED



ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™