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RF Technology for 5G mmWave Basestations

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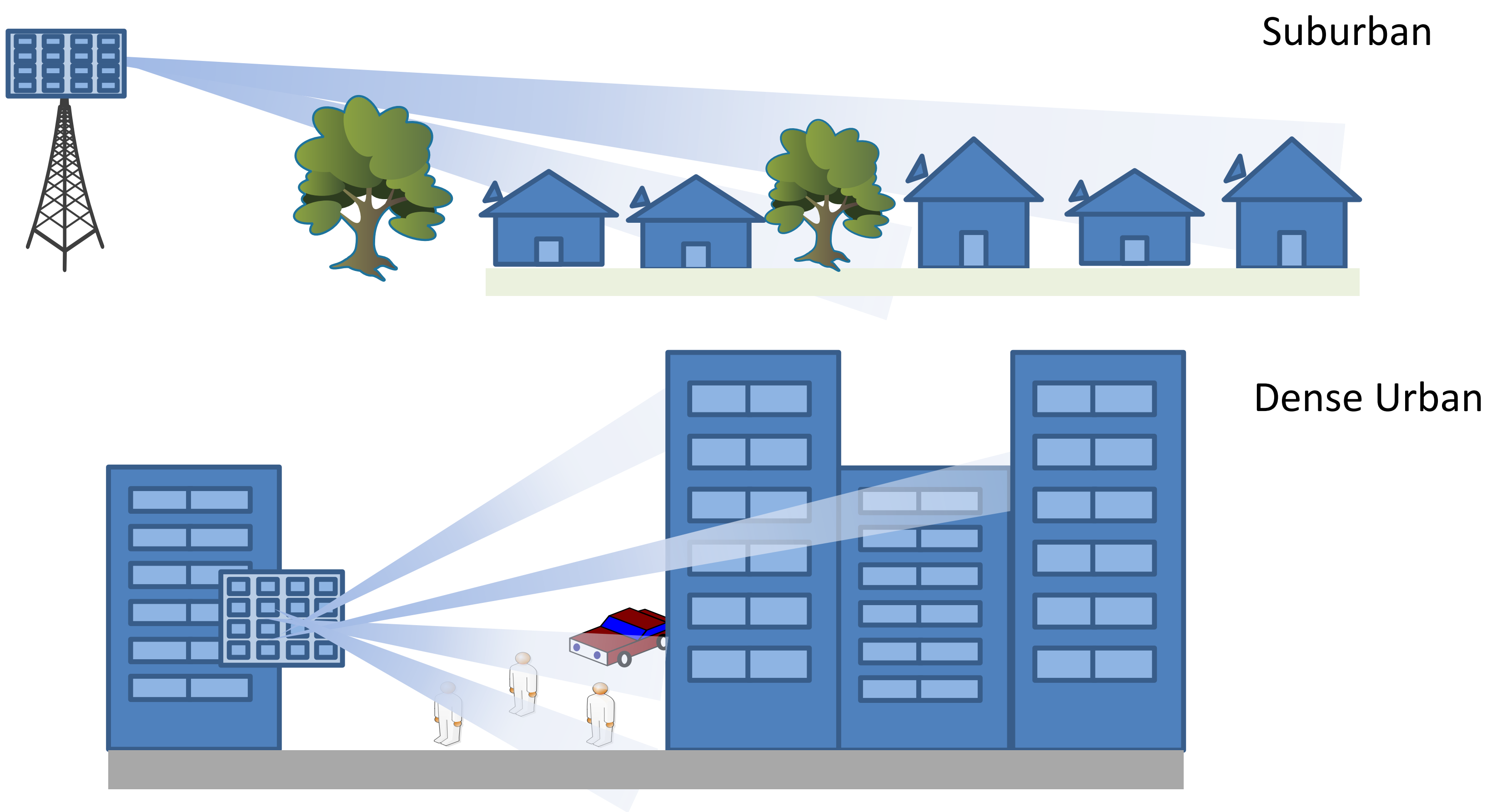
Analog Devices

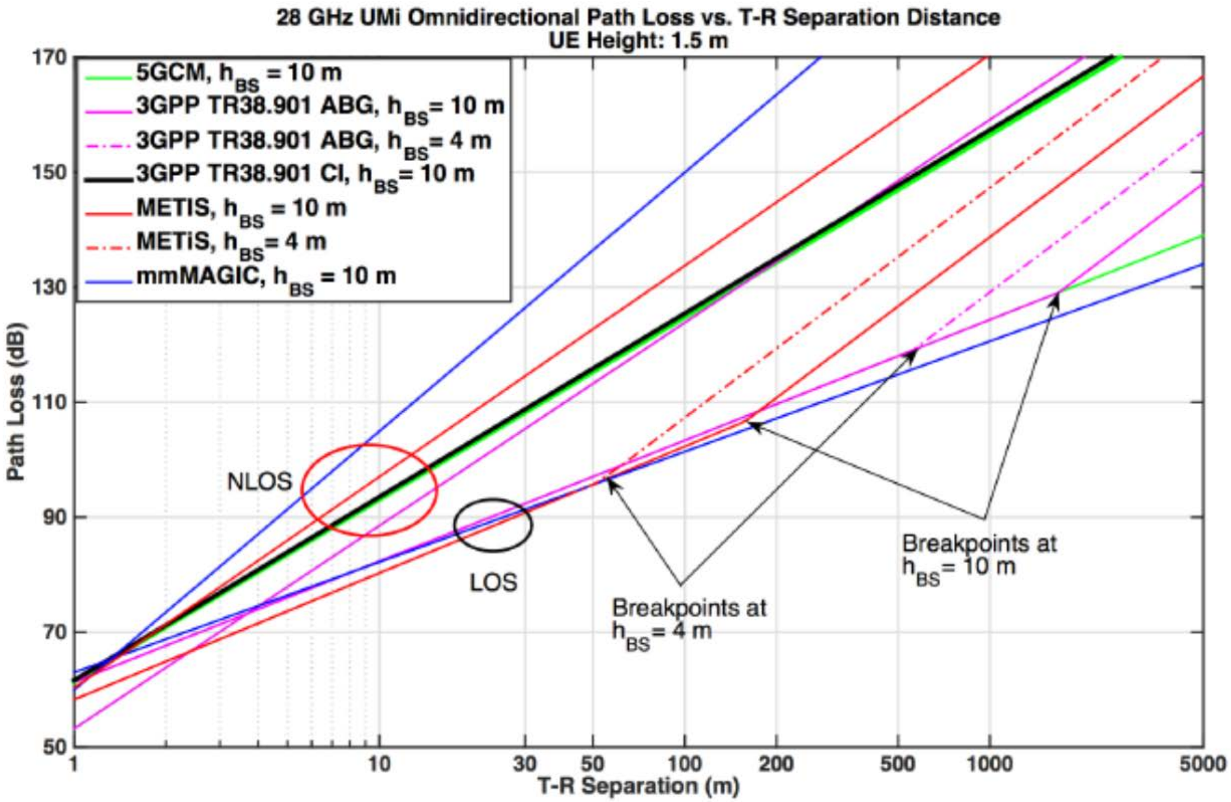
Agenda

- **mmWave Deployment**
  - **Path Loss**
  - **Typical Link Budget**
- **Beamforming architectures**
  - **Analog**
  - **Hybrid**
- **Bits-to-mmWave radio**
- **Q&A**

5G mmWave Deployment Scenarios



Path Loss

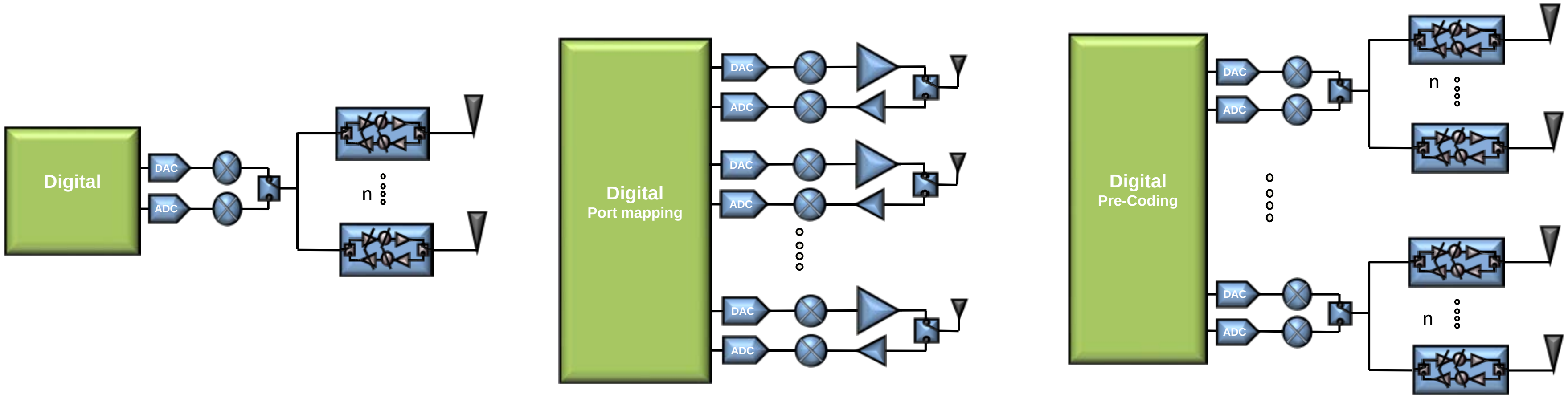


Reference: T. S. Rappaport et al, "Overview of Millimeter Wave Communications for Fifth-Generation (5G) Wireless Networks-with a focus on Propagation Models," in IEEE Transactions on Antennas and Propagation, Special Issue on 5G, Nov. 2017

Link Budget Example

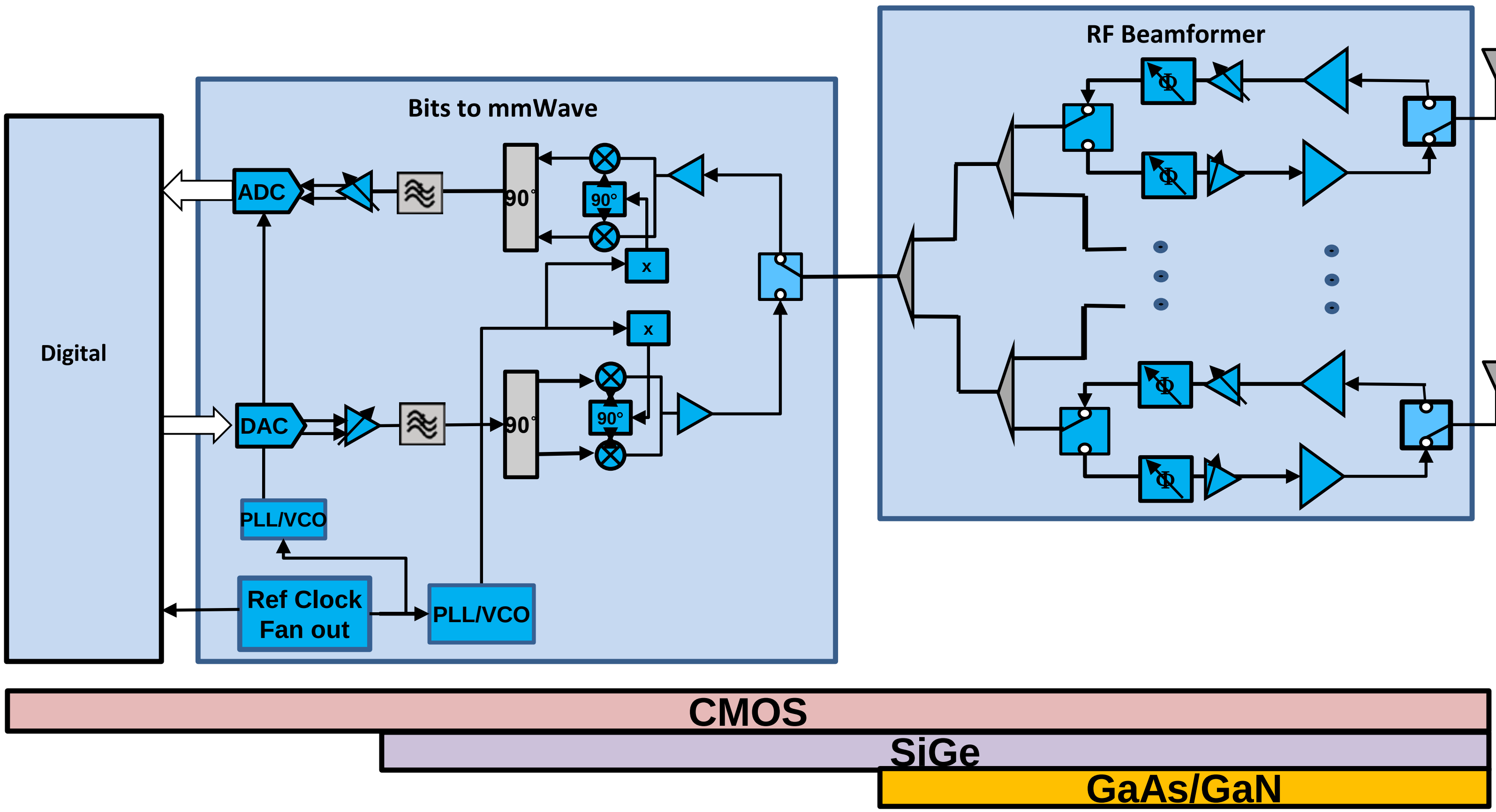
Link Budget 200m link @ 28GHz	Downlink (Access Point)	Uplink (CPE)
Total Conducted PA power	+33dBm	+19 dBm
Antenna Gain	27 dB	21
TX EIRP	60 dBm	40dBm
Path Loss	135dB	135 dB
Received Power	-75dBm	-95 dBm
Thermal noise floor	-85 dBm	-85dBm
RX Noise Figure	5dB	5dB
SNR per RX element	5dB	-15dB
RX Antenna Gain	21dB	27dB
RX SNR after beamforming	+26dB	+12dB

Beamforming Architectures



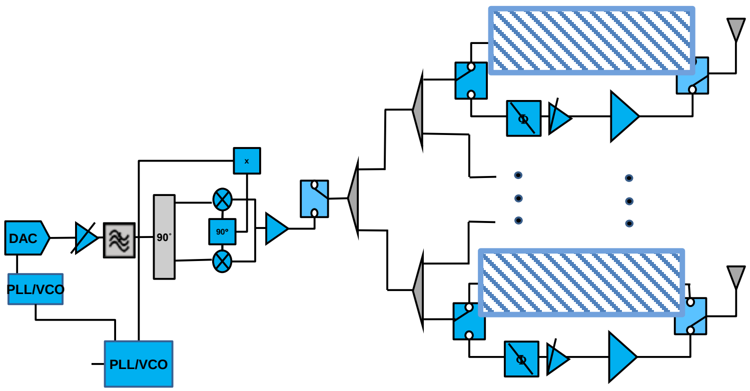
Analog Beamforming	Digital Beamforming	Hybrid Beamforming
Beam formed by weighting RF paths	Beam formed by weighting digital paths	Beamforming a combination of analog and digital
Low power/complexity	Highest power / complexity	Moderate power/complexity
Good for coverage	Highest capacity / flexibility	Compromise between analog and digital
Single beam – single data stream	Frequency selective beamforming	Best choice with existing technology

Analog Beamformer



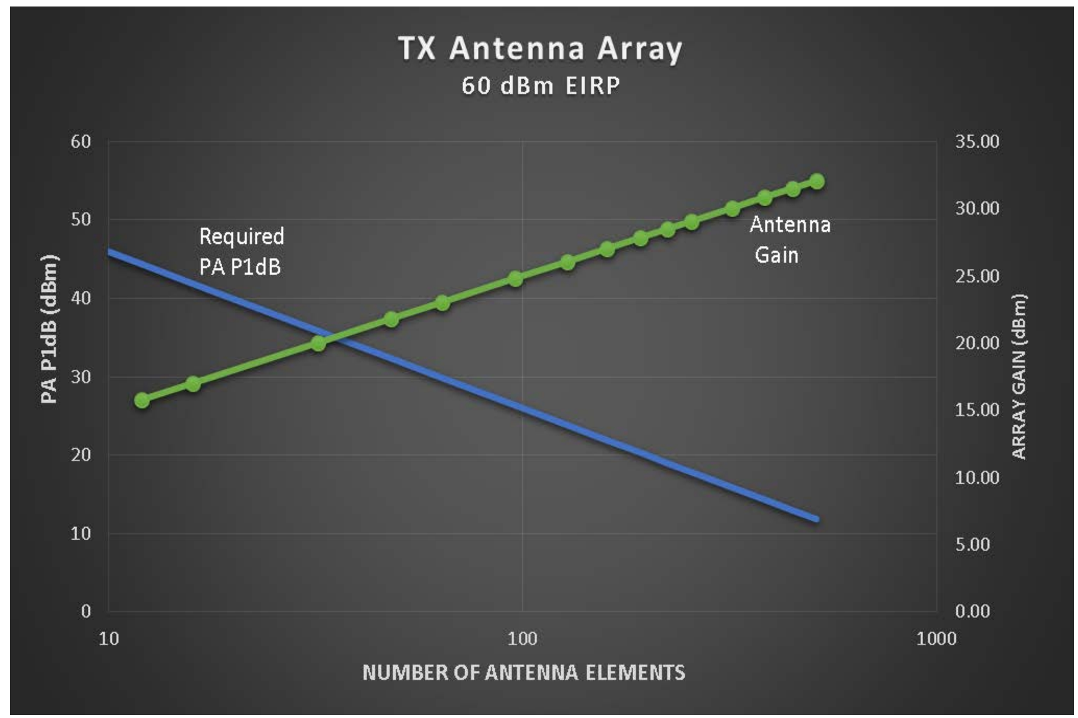
Analog Beamformer

TX Array Gain and PA Output Power vs Array Size at Fixed EIRP



Assumptions:

- 60dBm EIRP per beam
- 3-4 GHz IF, 800MHz BW
- PAPR =9 dB
- 2dB switch loss



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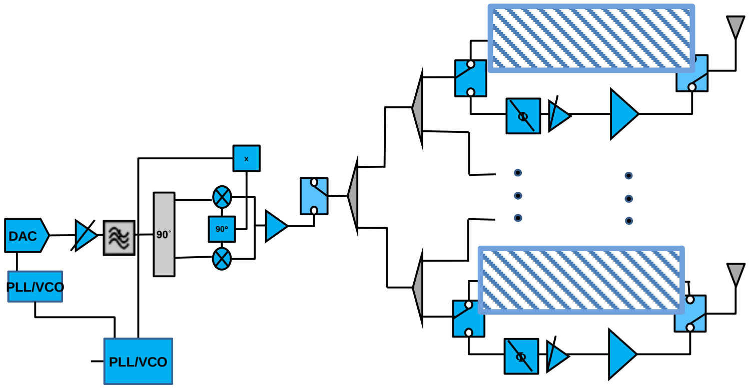

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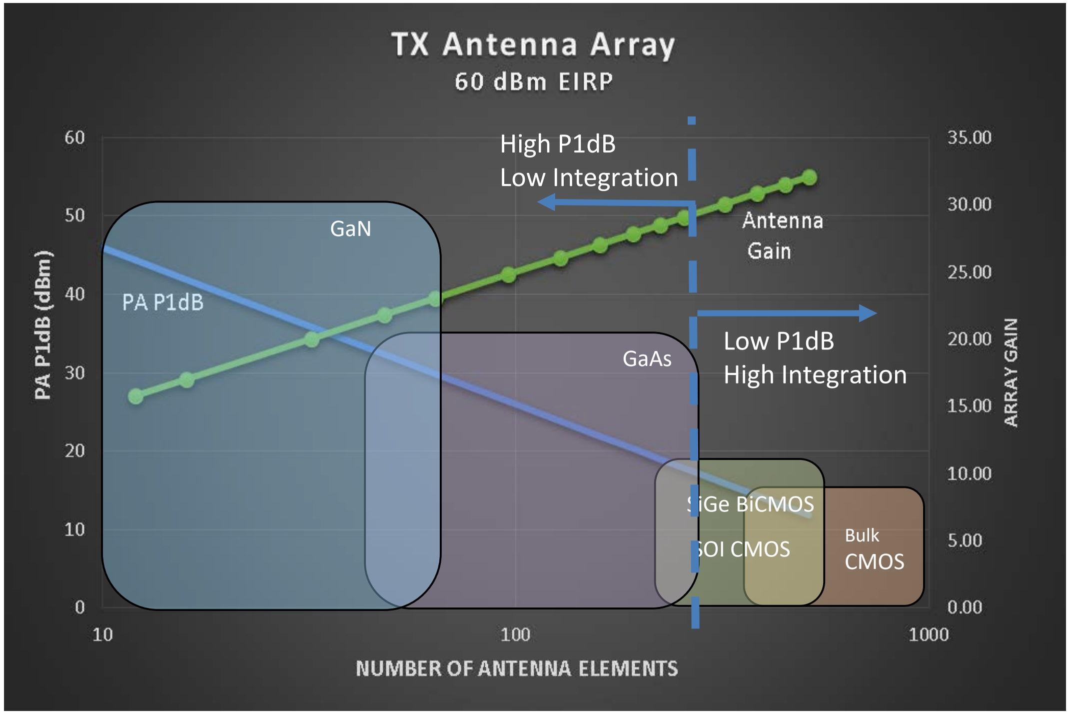
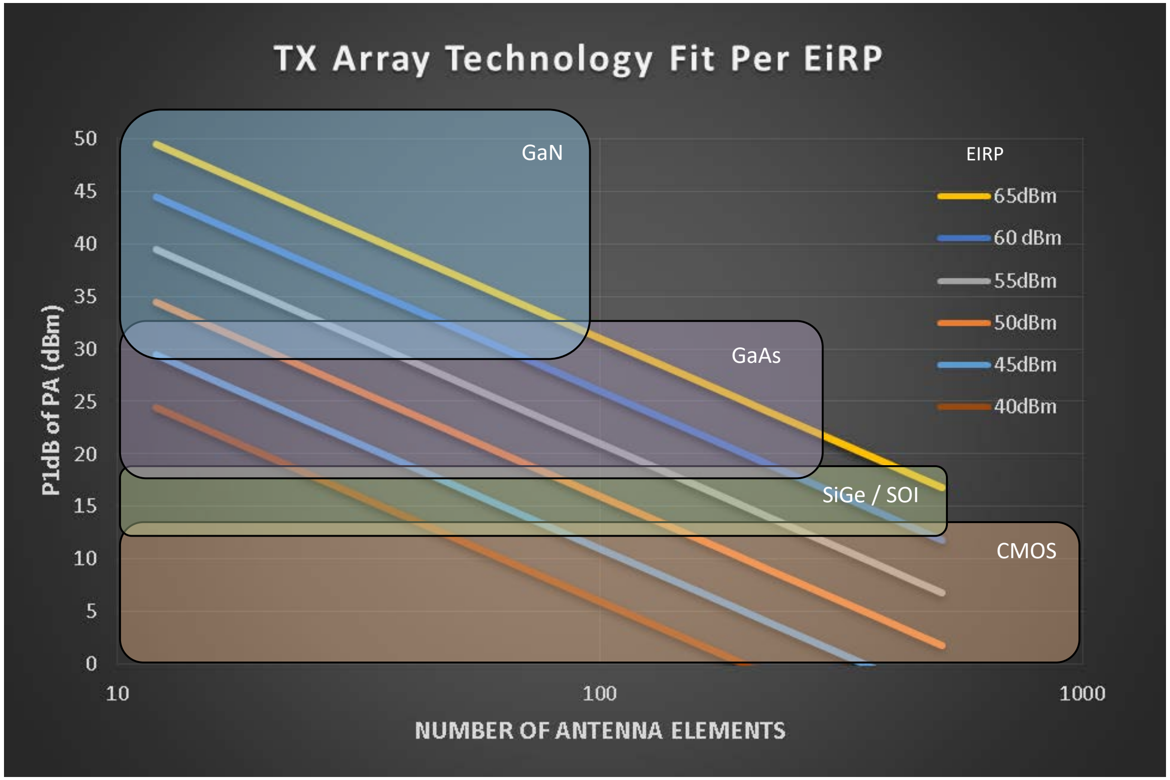


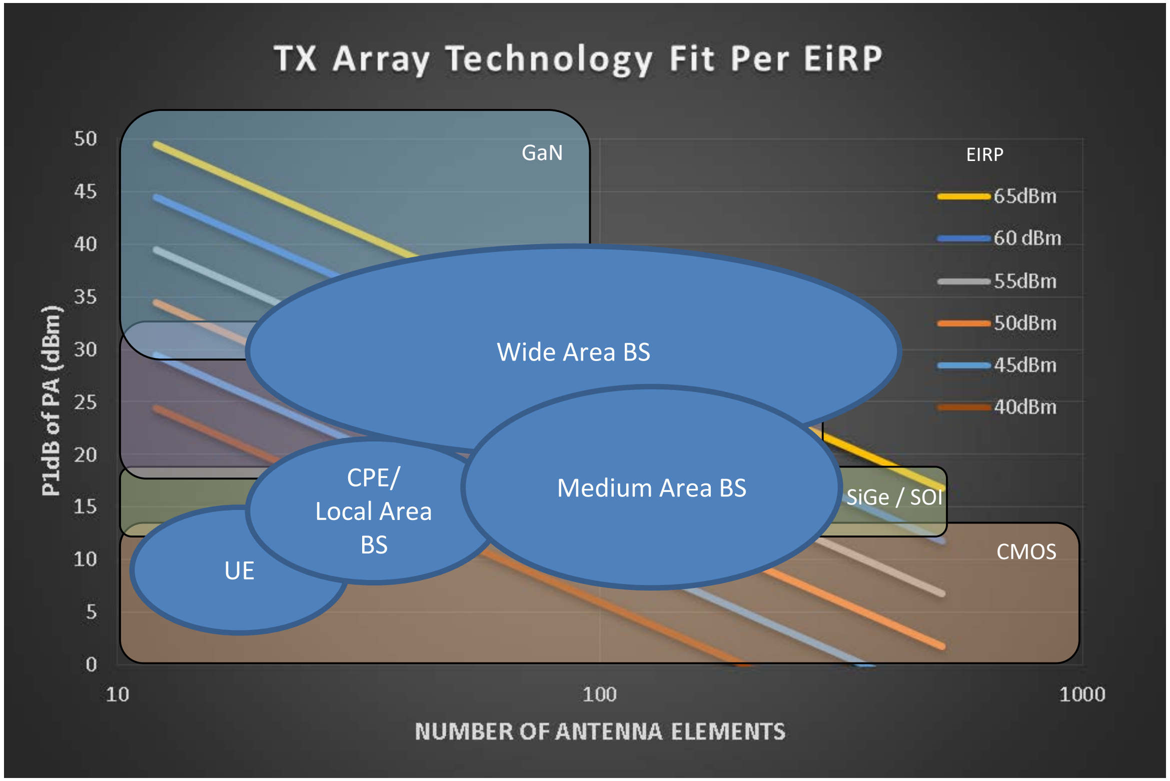
Technology Fit Per Radio Form Factor

- **Higher EIRP pushes PA technology toward III-V**
- **Lower EIRP allows for highly integrated silicon based solutions**
- **Larger array allows for the use of silicon PAs**
- **Larger array adds complexity and cost**



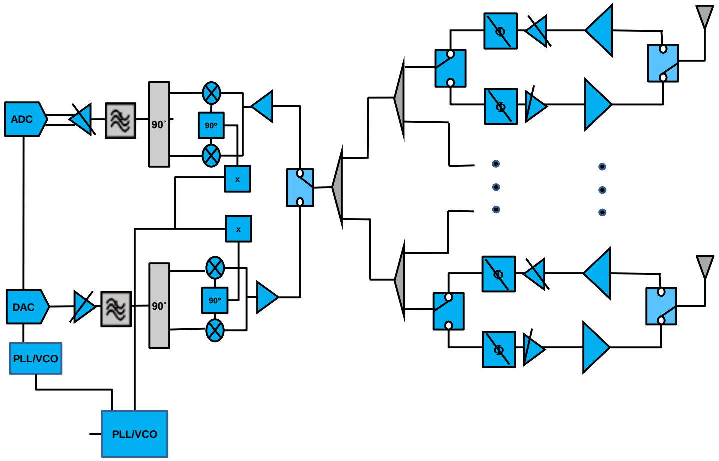
Technology Fit Per Radio Form Factor

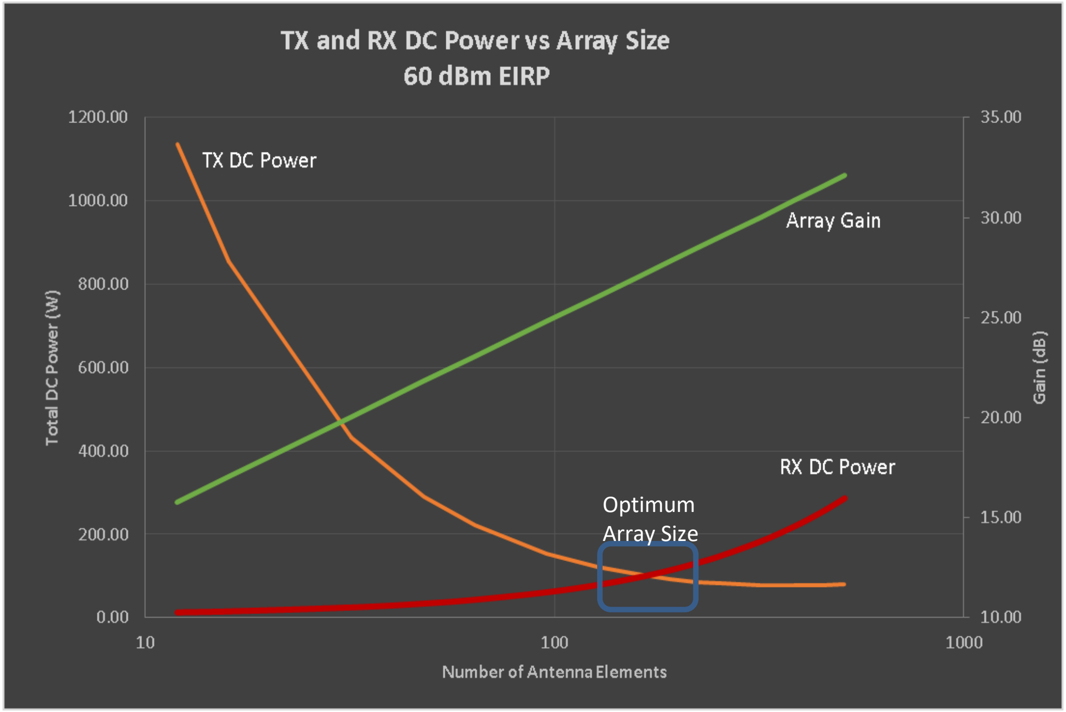
- **UE is clearly in CMOS technology domain**
- **CPE spans CMOS and SiGe BiCMOS**
- **Low power access point spans CMOS, SiGe BiCMOS and GaAs**
- **High power access point spans GaAs and GaN**



Analog Beamformer Power Consumption

TX and RX DC Power Consumption vs Array Size at Fixed EIRP



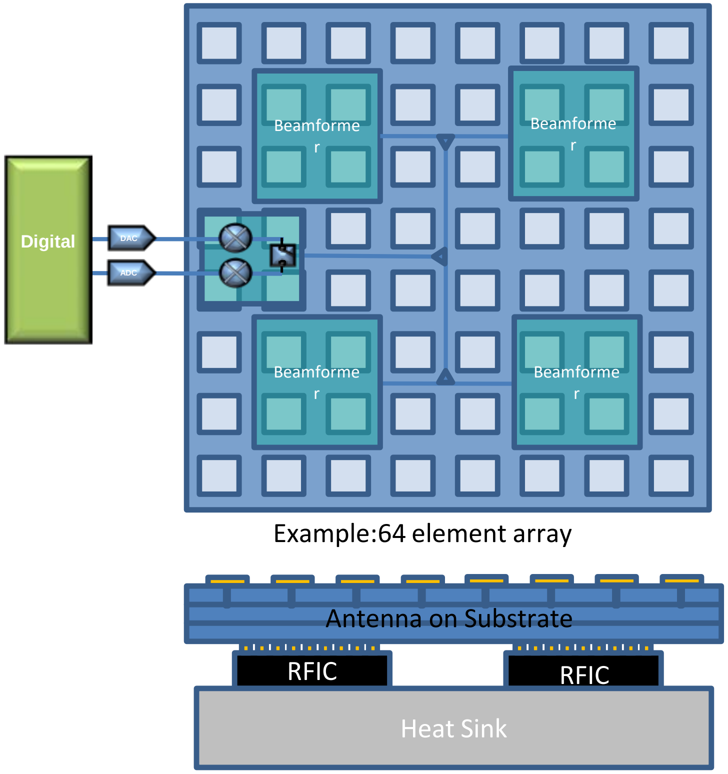


- Overlay TX and RX power consumption
- Optimum array size between 128 and 256 elements
- Power consumption ~80 to 100 W

High Integration Beamformer Assembly

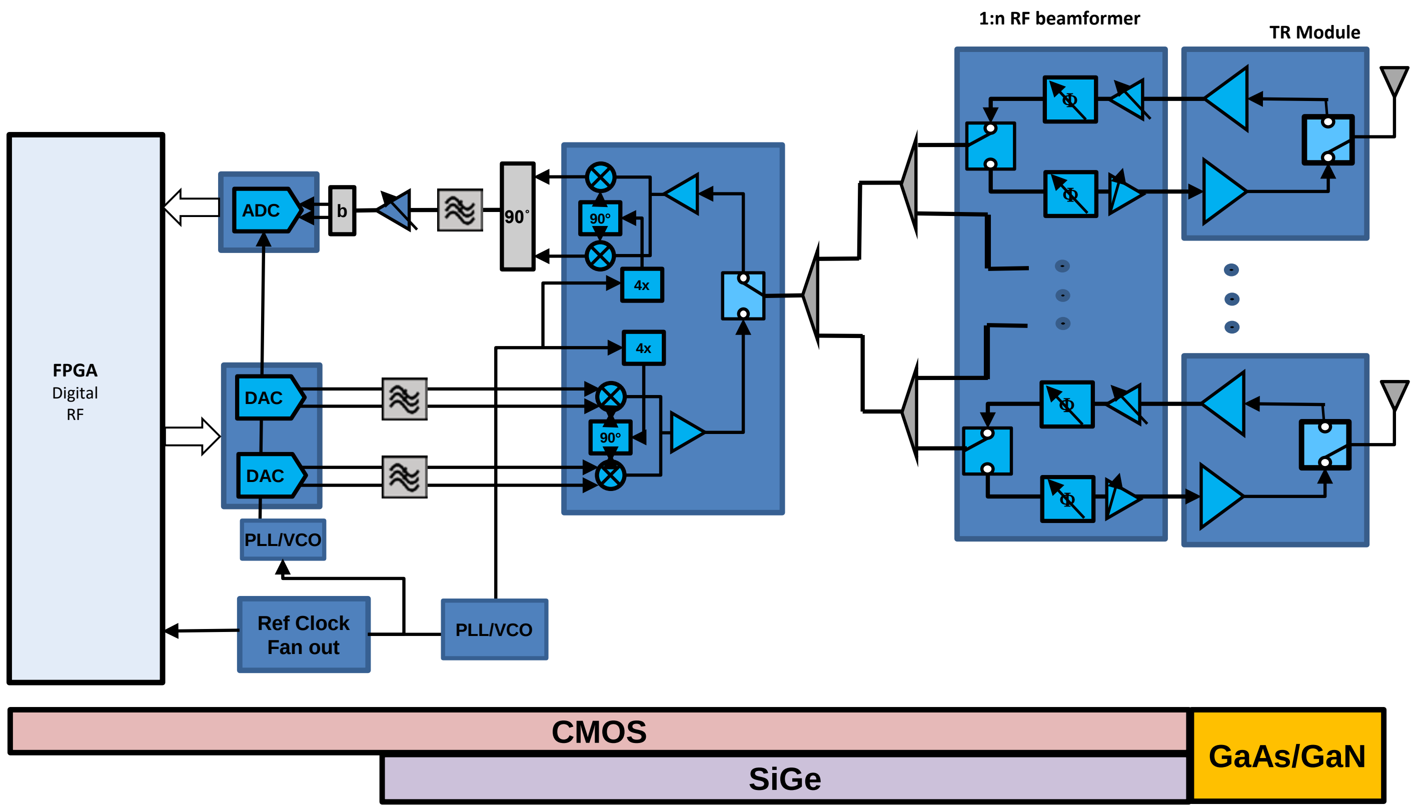
Antenna on Substrate

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



Semi-Integrated Analog Beamformer

Integrated Beamformer with TR Module



Semi-Integrated Analog Beamformer

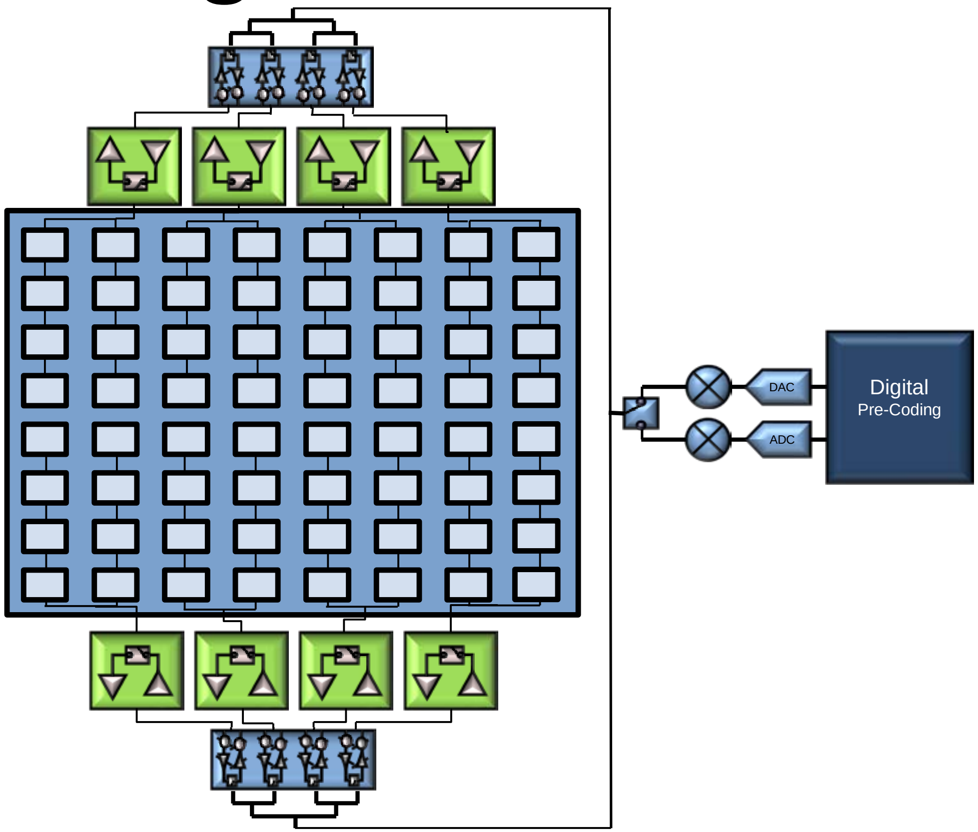
- Opt to drive a sub-array with each PA to leverage the array gain

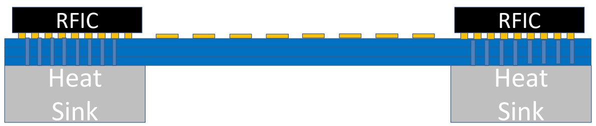
Pros:

- 8X less PAs and beamformer ICs
- Planar implementation
- Printed front end filters possible
- Conventional thermal management
- Scalable for very high EIRP

Cons:

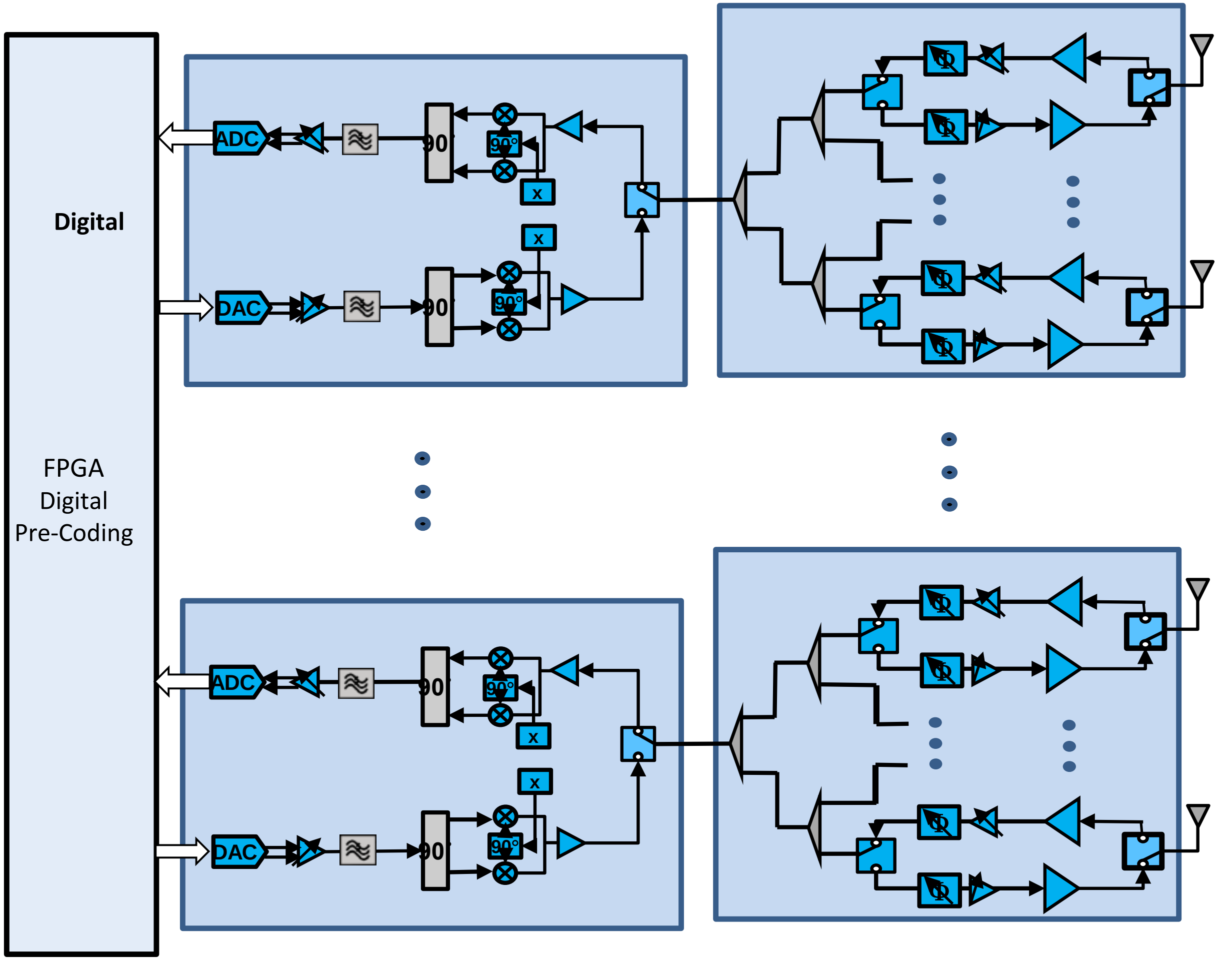
- Reduced scanning capability



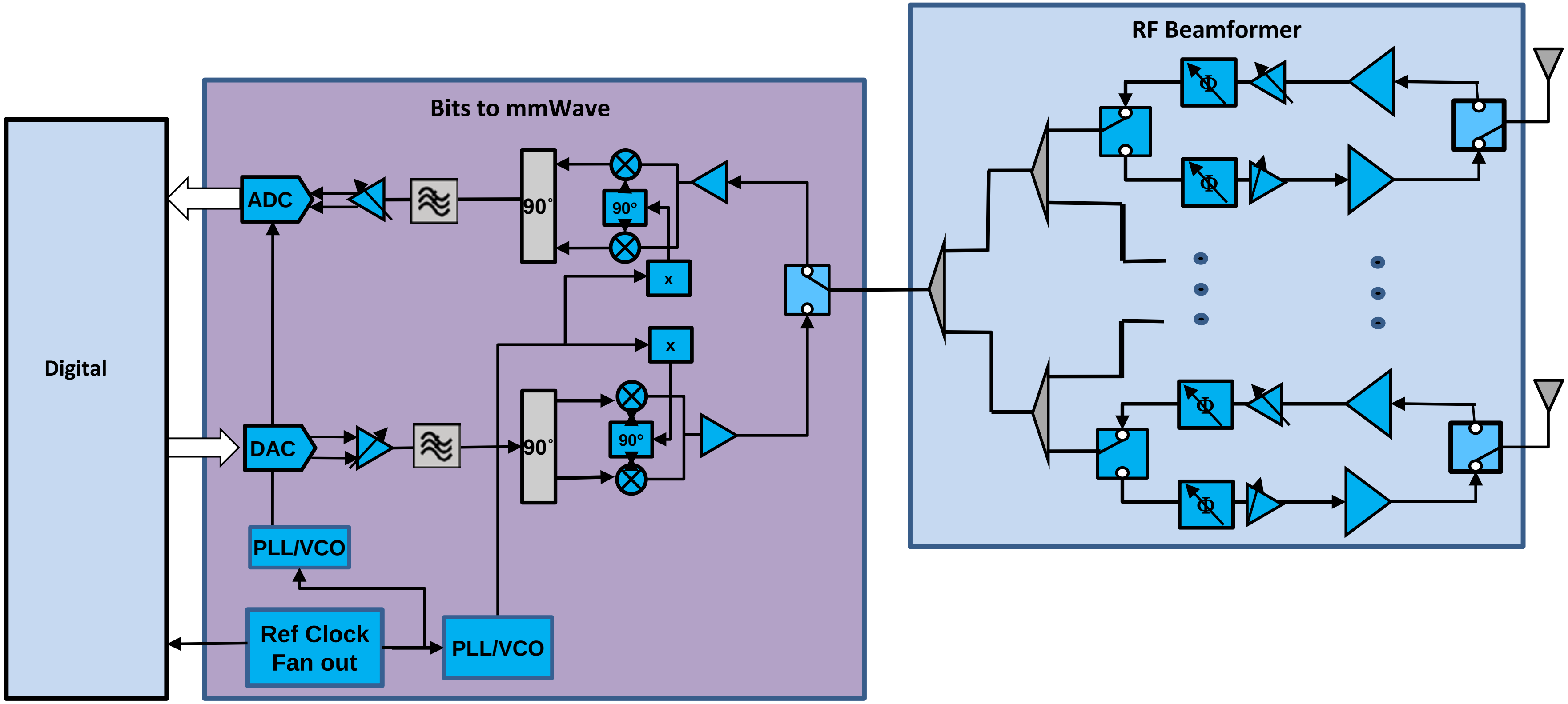


Hybrid Beamformer

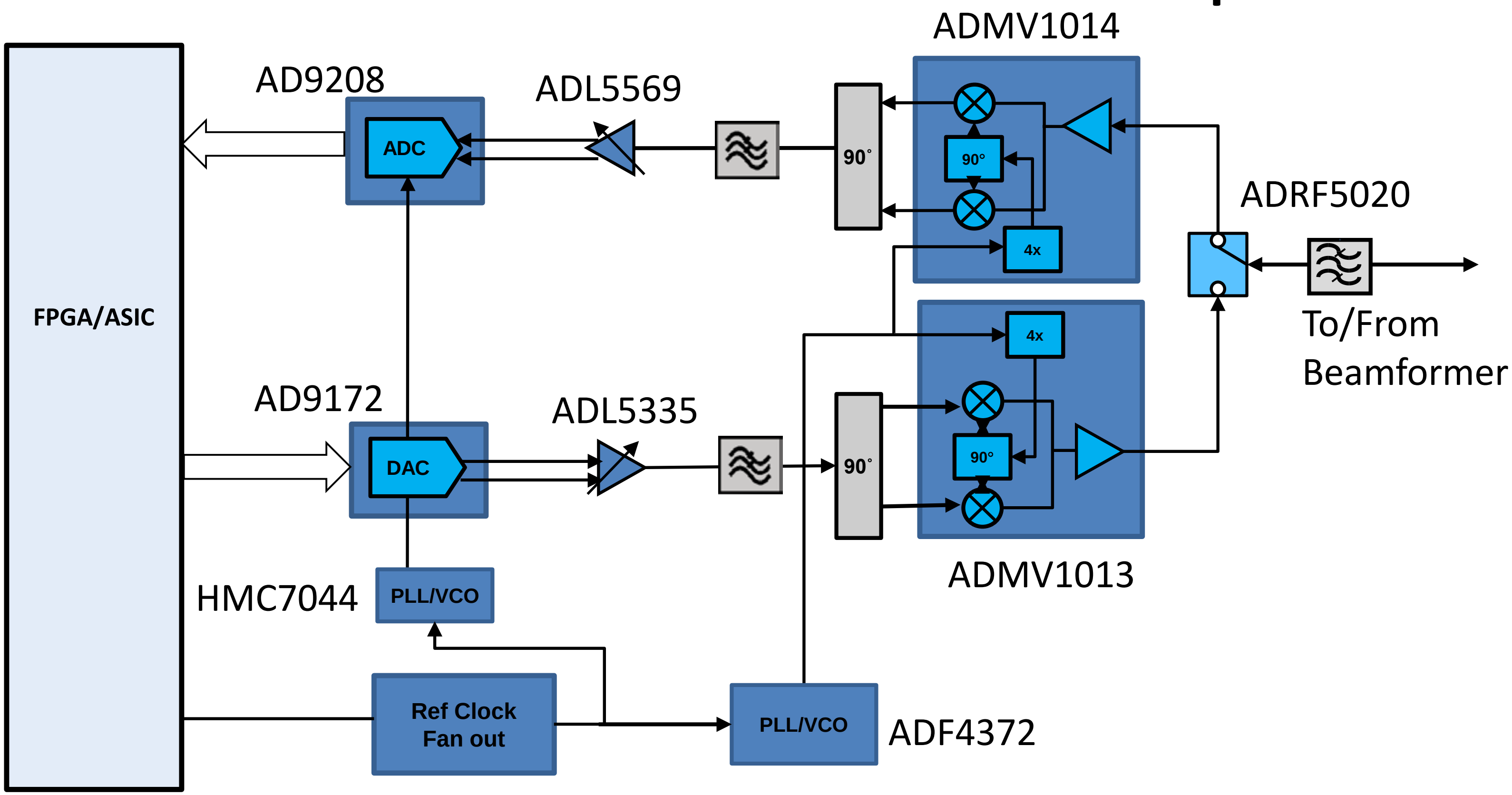
- Combines digital and analog beamforming to enable spatial multiplexing
- If m=8 and n = 128 then total array size is 1024
- While scalable - the power consumption adds up very quickly



Bits-to-mmWave Radio



Bits-to-mmWave Radio - Example



Reference: 5G Millimeter Wave Basestation,
http://www.analog.com/en/education/education-library/videos/5804450511001.html

Summary

- **5G mmWave use cases emerging**
- **Fixed in near term → nomadic → mobile in future**
- **Various approaches to beamforming**
  - **Analog Beamforming**
    - **Most efficient implementation with existing technology**
  - **Digital Beamforming in future**
- **Bit-to-mmWave Radio**
  - **Requires leading edge technology – available now!**