ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

ADI Views on mmW 5G

THE SILICON VALLEY 5G SUMMIT

JOHN KILPATRICK

SYSTEMS ARCHITECT

MICROWAVE COMMUNICATIONS GROUP

19 OCTOBER 2017

ADI 50 1965 2015

Agenda

- mmW 5G Goals
- Strategies to Achieve These Goals
- Beamforming
- mmW 5G Technical Challenges
- Architecture Discussion

Primary Goals for mmW 5G

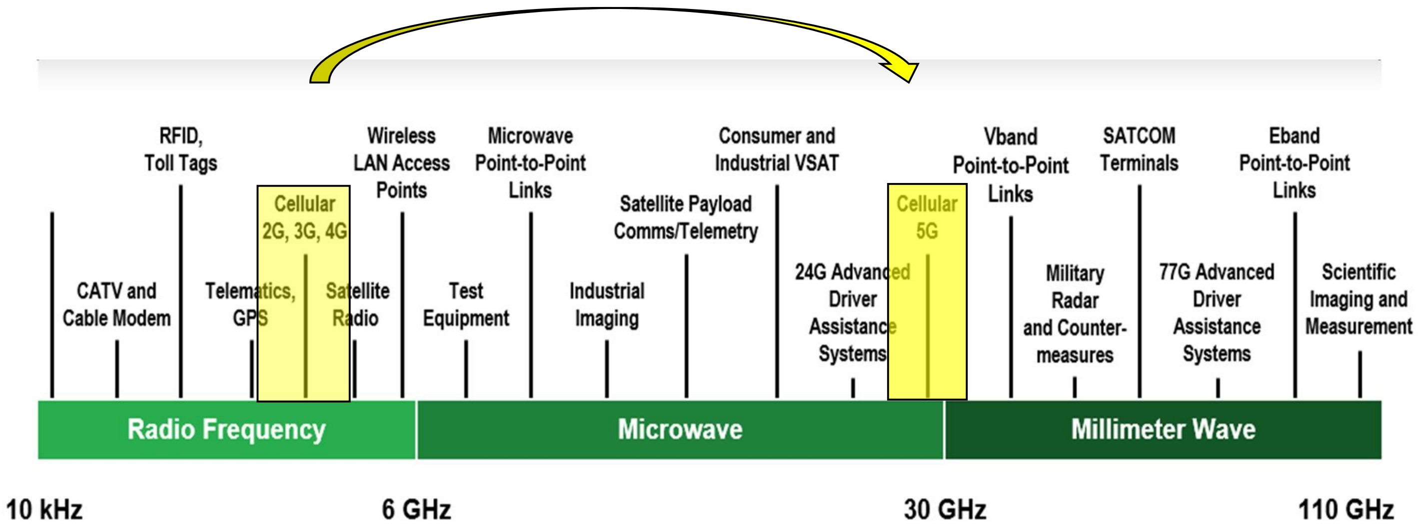
- Higher throughput
- Higher capacity
- Higher spectral efficiency
- Less latency
- Lower power

5G Vision

IMMERSIVE EXPERIENCE
Enhanced
Mobile Broadband
5G
FOR EVERYTHING
Massive
Machine Type Communication
INSTANT ACTION
Ultra Reliable
Machine Type Communication
Immersive entertainment and experiences
Reliable access to remote healthcare
Improved public safety and se
efficient use of energy/utilities
More autonomous manufacturing
Sustainable cities and infrastructure
Digitized logistics and retail

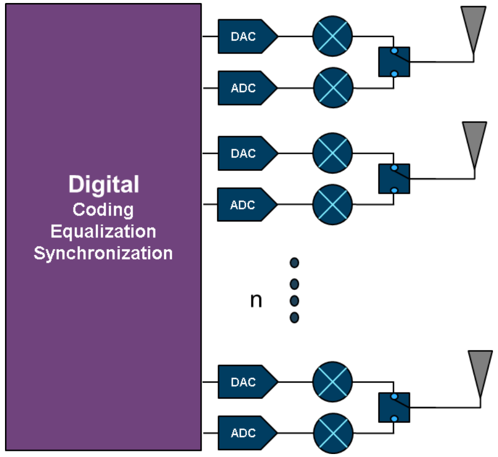
How to Meet these Goals

- Build on 4G
  - OFDM-like Waveforms
  - Antenna Arrays
- Move to Higher Frequencies
  - Greater Bandwidth
    - More users; more throughput
  - Smaller Antennas
    - Allows higher antenna gains
  - Beamforming
    - Overcome higher path loss
    - Spatial isolation
    - Better use of spectrum
- Increase Integration



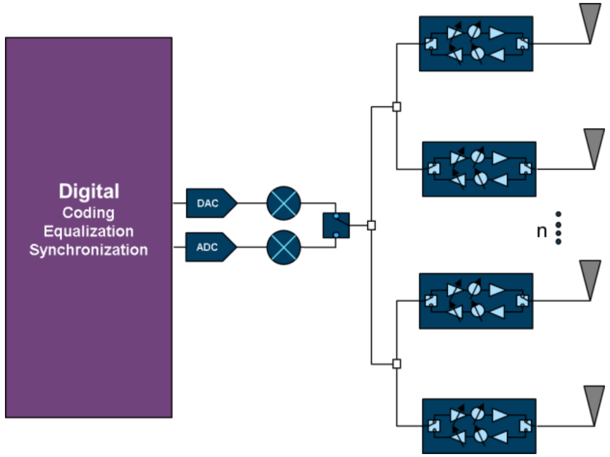
Beamforming Solutions

- Digital Beamforming (DBF)



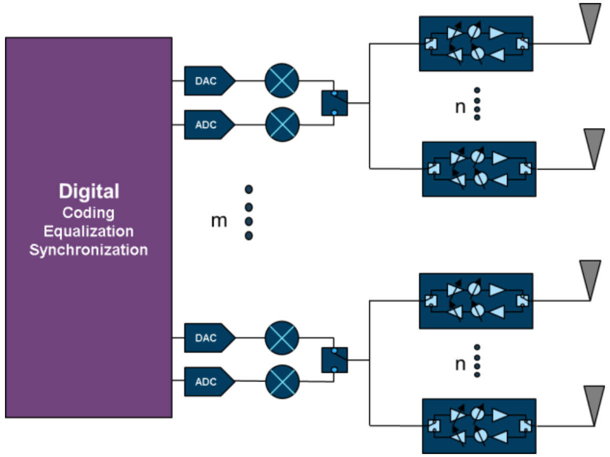
- Pros
  - Most flexible
  - Most capacity
  - Steer multiple beams and nulls
- Cons
  - Very high power and cost of digital processing / transport
  - No spatial rejection from FE

- Analog Beamforming (ABF)



- Pros
  - Relatively low cost
  - Much lower DSP
  - Low power consumption
- Cons
  - Single beam
  - Single stream

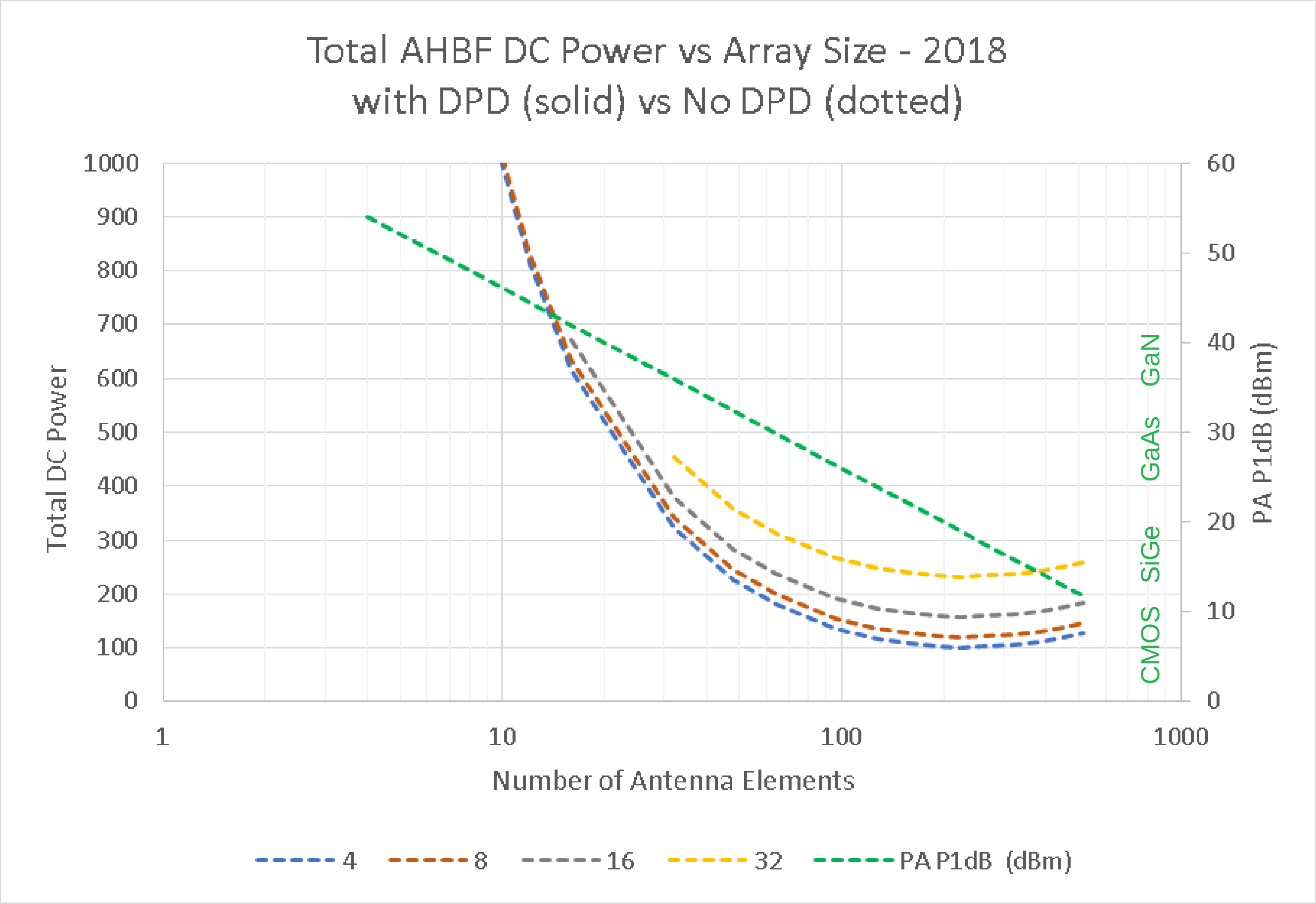
- Hybrid Beamforming (HBF)



- Pros
  - More capacity than ABF
  - Much lower complexity / power than DBF
- Cons
  - Harder to perform MIMO processing

Array Size Optimization for 60 dBm EIRP

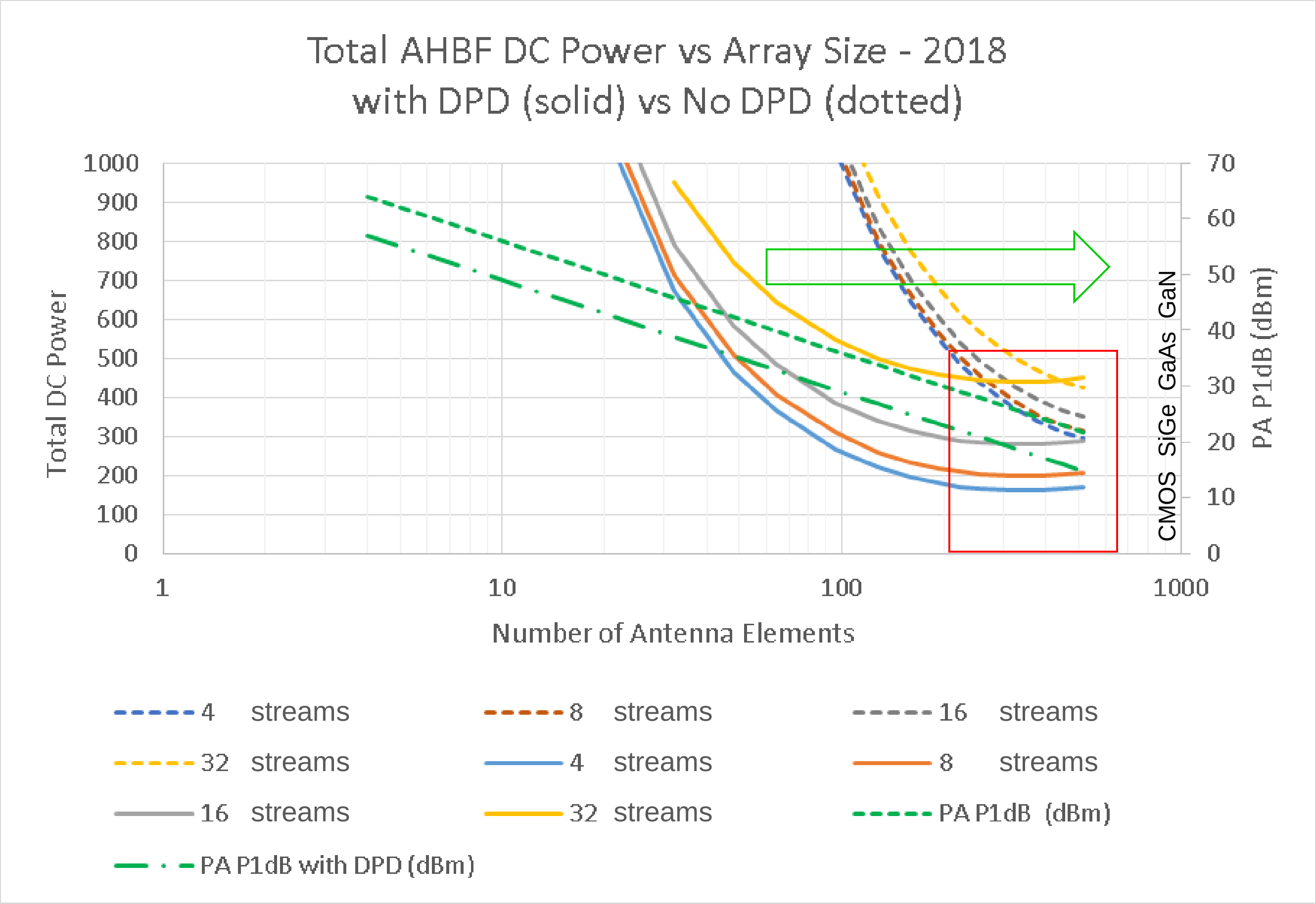
- ▶ Smaller arrays have less gain and therefore require more power per element
  - – GaAs or GaN PAs dominate power consumption
  - – DPD has large benefit
- ▶ Larger arrays have much higher gain and therefore require less power per element
  - – Can be SiGe or CMOS (see green curves)
  - – DPD has much smaller or even negative impact!
- ▶ Conclusion
  - – With DPD: 64-128 elements
  - – Without DPD: 128-256 elements
  - – High power PA's not optimal!



ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

Array Size Optimization for 70 dBm EIRP

- Optimum array size
  - With DPD: about 256 elements with ≤22 dBm PAs
  - Without DPD: >512 elements with ≤20 dBm PAs



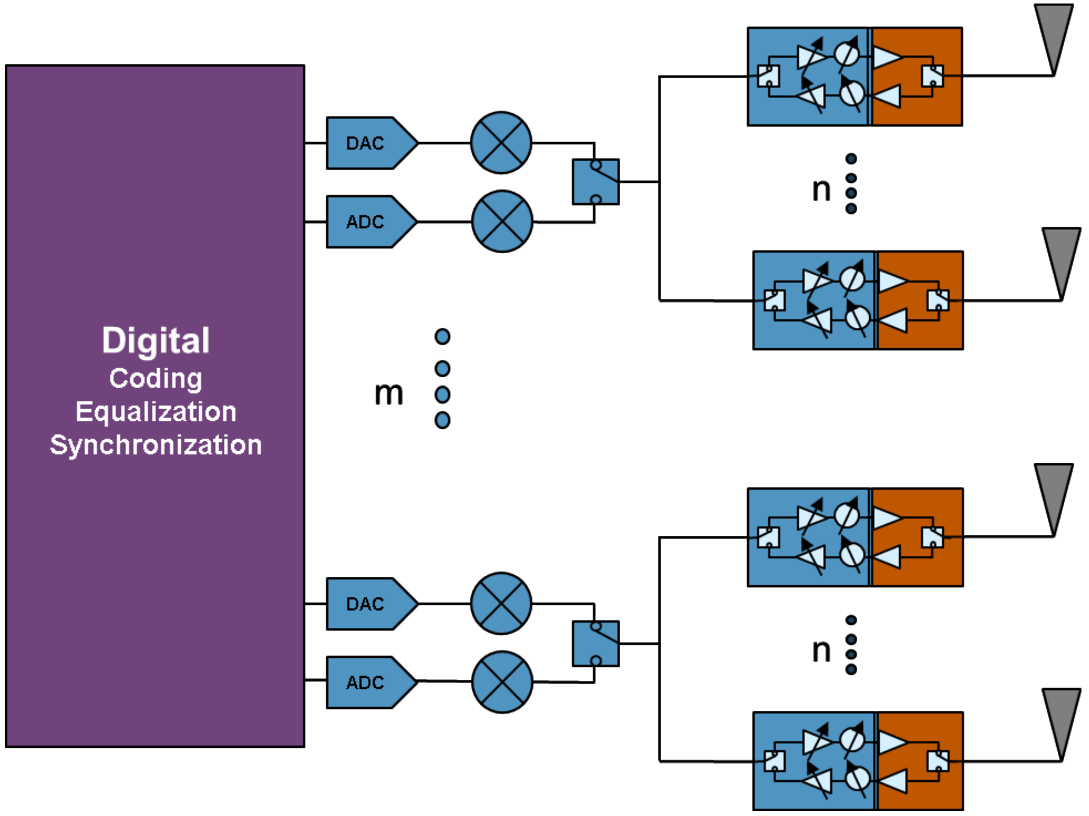
Five Significant Challenges for mmW 5G

- Reduce digital power consumption to enable more capacity and move towards DBF
  - Data converters
  - JESD lanes
- Wideband DFE processing
  - QEC and CFR
  - Spur reduction/cancellation
- Improve PA efficiency
  - Currently ~2-4% for each antenna element without DPD
  - How to perform DPD over N PAs in sub-array
  - Or comparable PA efficiency technique (envelope tracking, Doherty, …)
- Calibration of gain/phase to allow accurate beam steering and interference rejection
  - Within a sub-array
  - Between sub-arrays (to allow combining of sub-arrays)
  - Reduce or eliminate phase variation with gain (and gain variation with phase) to reduce calibration complexity
  - Phase synchronize multiple LO’s over M streams
- Shrink mmW electronics to fit in back of antenna array
  - $\lambda/2$ between 4-6 mm for the 25 – 39 GHz bands

Chipset Architectures

- HBF block diagram shown at right
- Macrocell may have individual chips for each function (including PA)
  - Many designs use a high IF configuration with digital board and microwave board
- CPE will support fewer (1?) stream and silicon PAs
- UE may have all functions integrated into one chip

- Can CPE chipset be used to construct Macro BTS?
- Will traditional PAs disappear from BTS designs?



Summary

- Full DBF at mmW still a number of years off (if ever!)
  - ADI actively investigating improved transceiver, converter and transport technologies
- HBF is currently most cost effective architecture to achieve mmW 5G goals
  - Different chipset architectures for the various use cases / applications
  - ADI has chipsets / technologies to form the complete HBF radio chain
- Looking to work with ecosystem partners and customers as the standards evolve toward high volume deployments

ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

THANK YOU!