Mobile Radio Transformation in the Age of 5G: A Perspective on Opportunities for SOI

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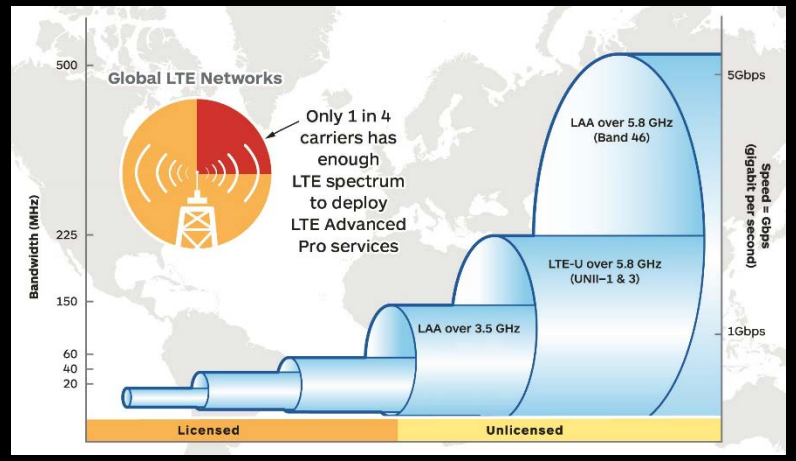
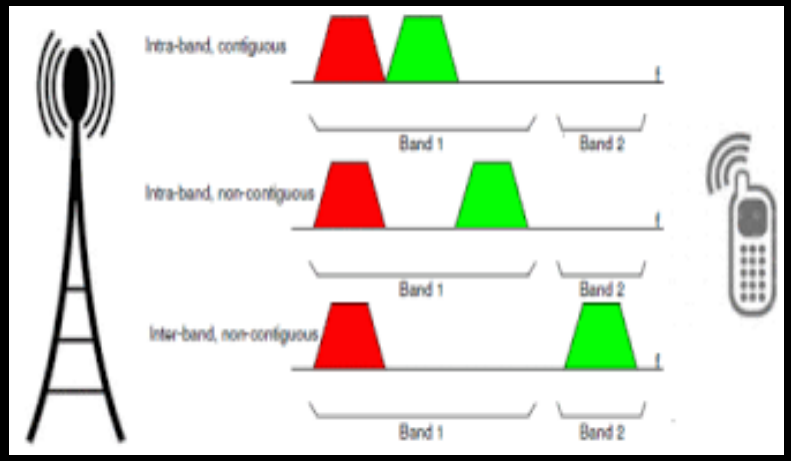
7 key trends that drove this year's Mobile World Congress…

5G NR standards are driving increasing radio complexity and cost

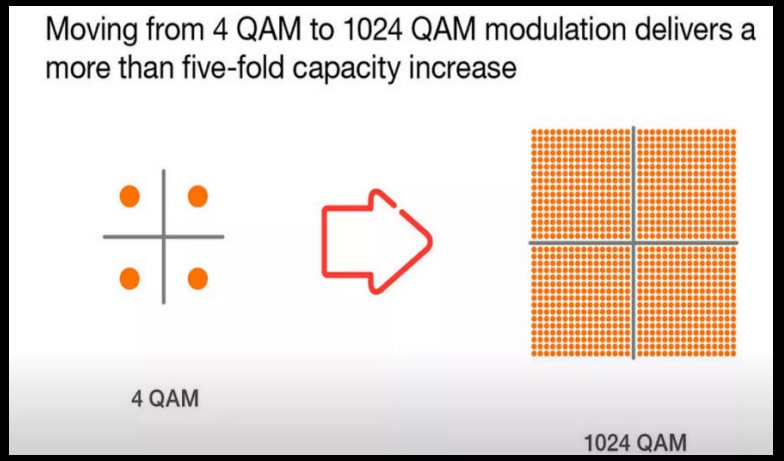
Increasing Number of Bands



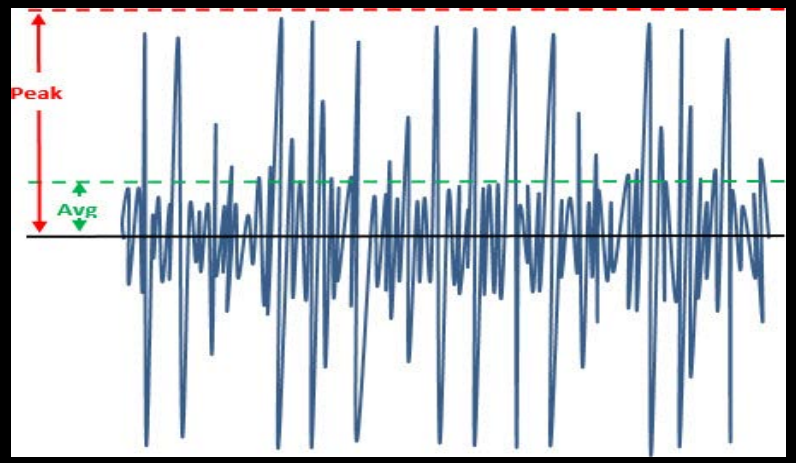
Carrier Aggregation



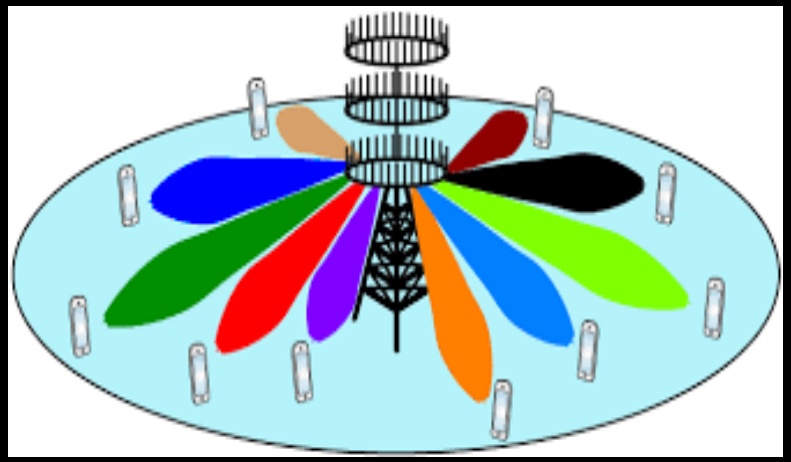
Complex Modulation Waveforms



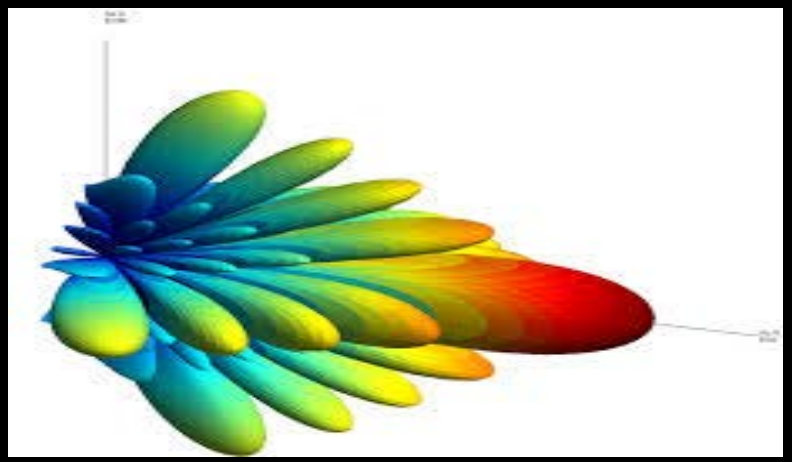
Stringent Peak-to-Average Power



Massive MIMO

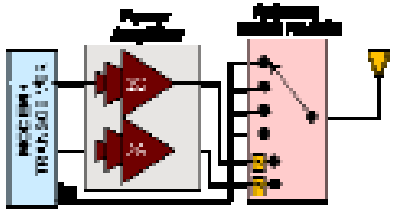


Phased Arrays & Millimeter Wave



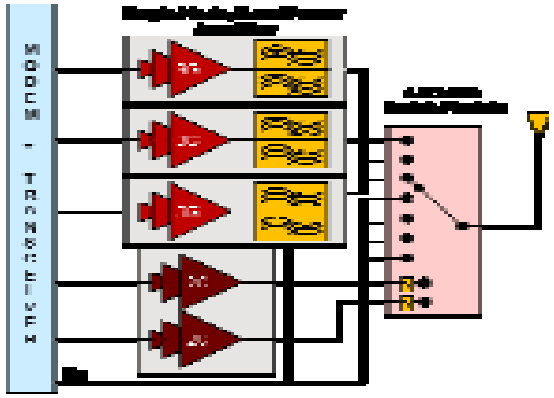
We are well-versed in how sub-6 GHz FEMs have changed over time in response to higher CAT support…

2G



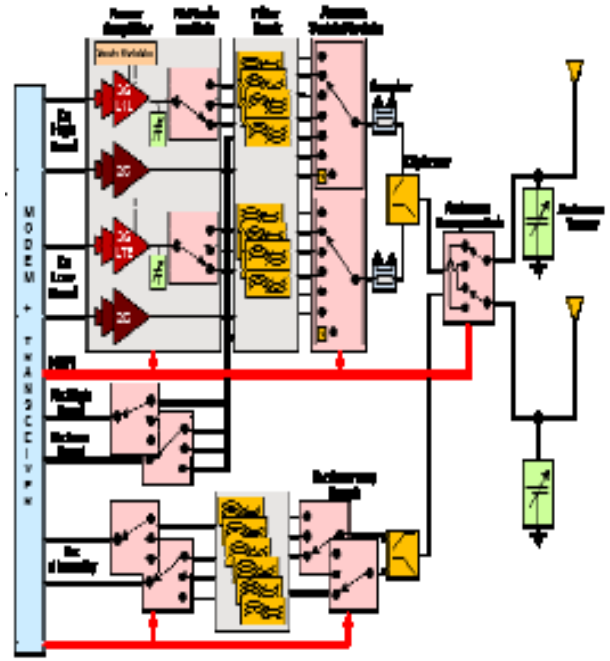
Max #bands 4

3G



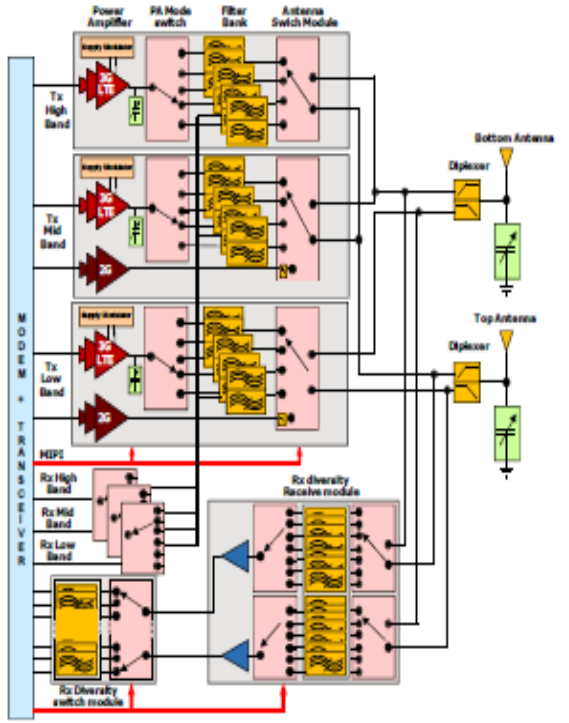
Max #bands ~10

LTE



Max #bands ~20

LTE Advanced



Max #bands >30

Growth of bands added to complexity due to other features like carrier aggregation, MIMO etc.

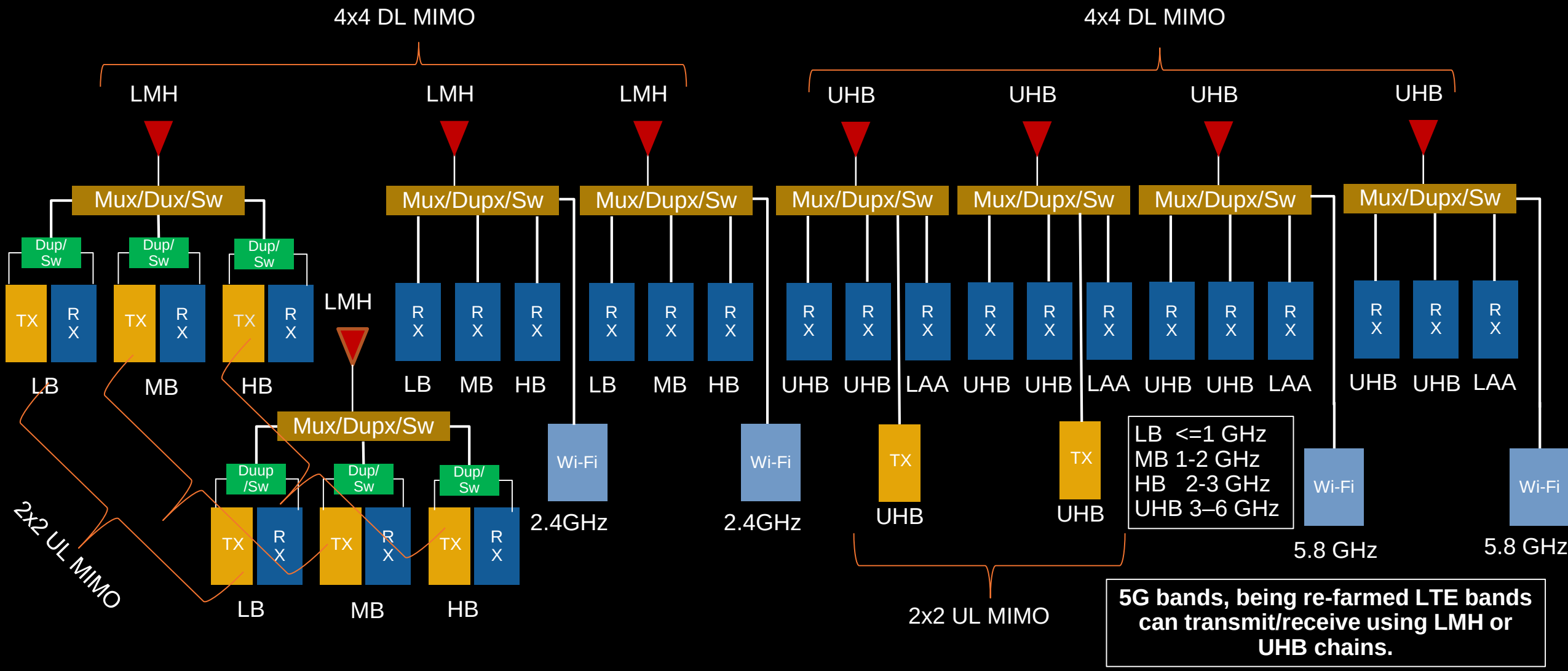
5G NR sub-6GHz frequency band specifications significantly increase frequency range and channel bandwidth

- Sub 6 GHz 5G bands will have 5,10, 20, 25, 30, 40, 50, 60, 80,100 MHz channel bandwidths

Band UL Frequency Range	Max Channel BW
N41 (2.46-2.69 GHz) N77 (3.30-4.20 GHz) N78 (3.30-3.80 GHz) N79 (4.40-5.00 GHz)	100 MHz (4%)
N50 (1.43-1.52 GHz)	80 MHz (5.6%)
N66 (1.71-1.78 GHz)	40 MHz (2.3%)
N3, N80 (1.71-1.78 GHz)	30 MHz (1.8%)

- Bands N1, 2, 5, 7, 8, 20, 28 (all FDD), F38, 51 (TDD), F71, 74 (FDD), and F76, 81-84 have channel BW of 20 MHz or less, like 4G

Growth in RF FEM complexity and die size per handset prompted by new band support and MIMO



GLOBALFOUNDRIES has been at the forefront of RF SOI innovation to address evolving FEM requirements

2008

7RF SOI (180 nm)
Fab 9 & 10
200 mm

- Performance, area and value
- Purpose-built options

2015-16

130RFSOI (130 nm)
Fab 7
300 mm

- Up to 30% better switch performance and smaller chip area*
- 130RFSOI: 20% better Ron*Coff than 7RF
- LNA introduced
- Latest 130RFSOI PDK released Q3'16

2014-16

7SW / 7SWe (180 nm)
Fab 9 & 2
200 mm

- 7SW: Up to 30% better switch performance and smaller chip area*
- 7SWe: 20% better Ron*Coff than 7SW
- 7SWe: 10% better Ron*Coff than 130RFSOI
- LNA better than 130RFSOI
- Fully qualified & in volume production

2017

8SW (130 nm)
Fab 10 & 7
300 mm

- Up to 50% better switch performance, 40-50% smaller chip area*
- LNA performance Fmax=250 GHz
- Better series harmonic performance (better by 5 dB)
- Both 1.8 V &1.2 V libs available
- Fully qualified & production ready

*Compared to 7RF SOI. Performance and area advantages will vary with chip design.

5G/mmWave phased arrays drive a paradigm shift in the approaches that can be taken…greater integration is needed

Analog beamforming

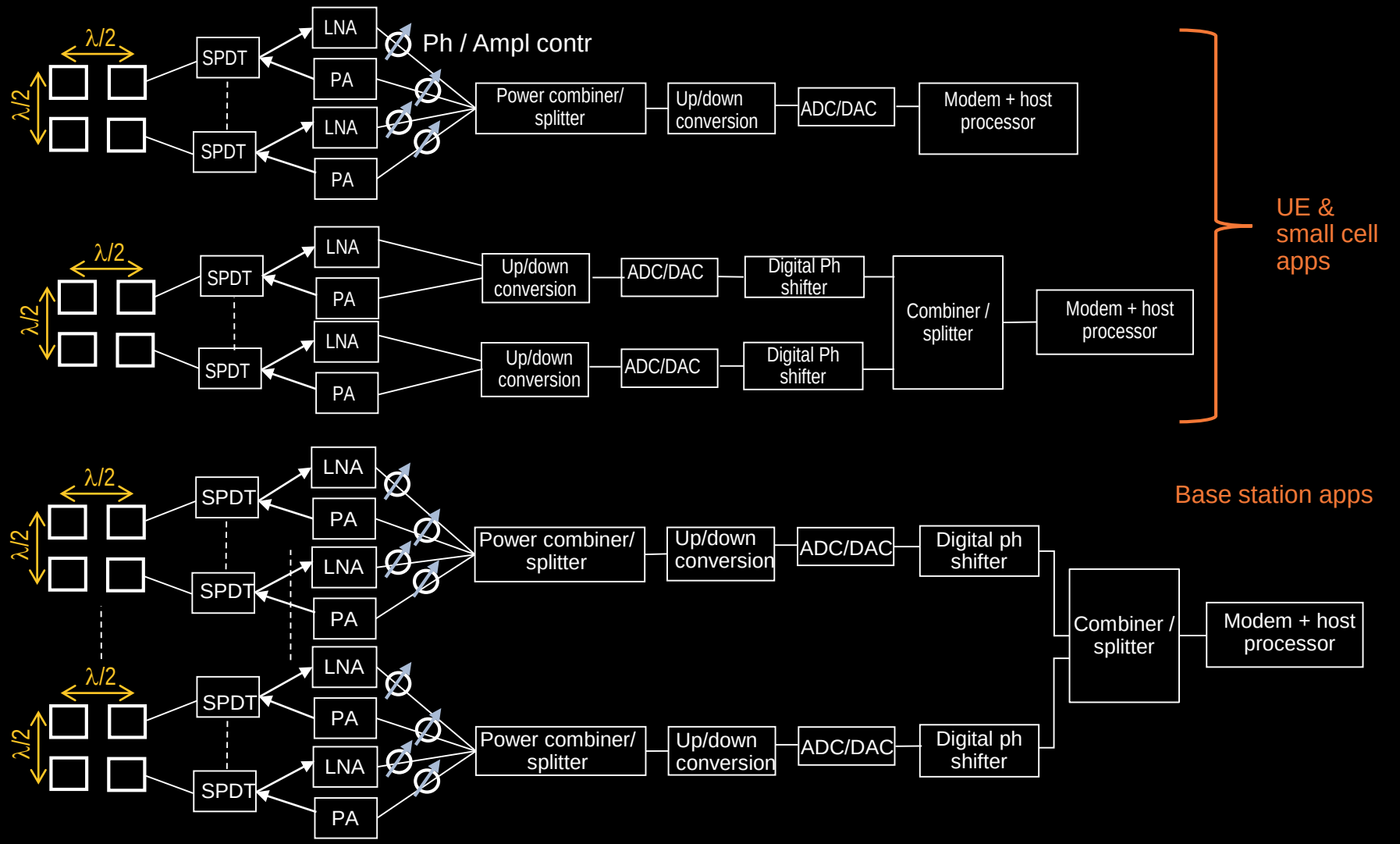
- Smallest # of components
- Lowest power dissipation
- Most sensitive to interconnect loss
- Complexity in phase shifting

Digital beamforming

- Large # of components
- High power dissipation (except for FDX)
- Simple to implement

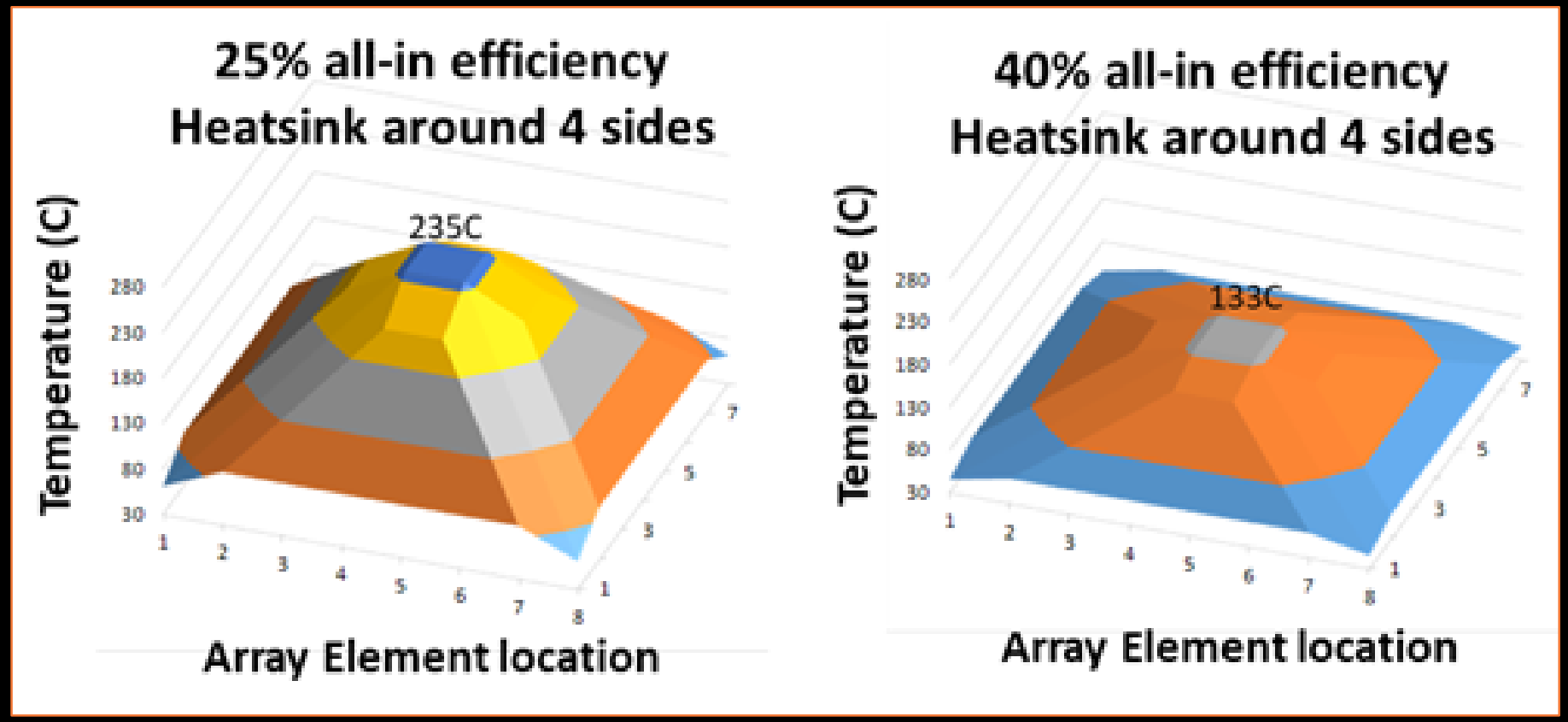
Hybrid beamforming

- For large array where analog & digital beamforming are inefficient and complex



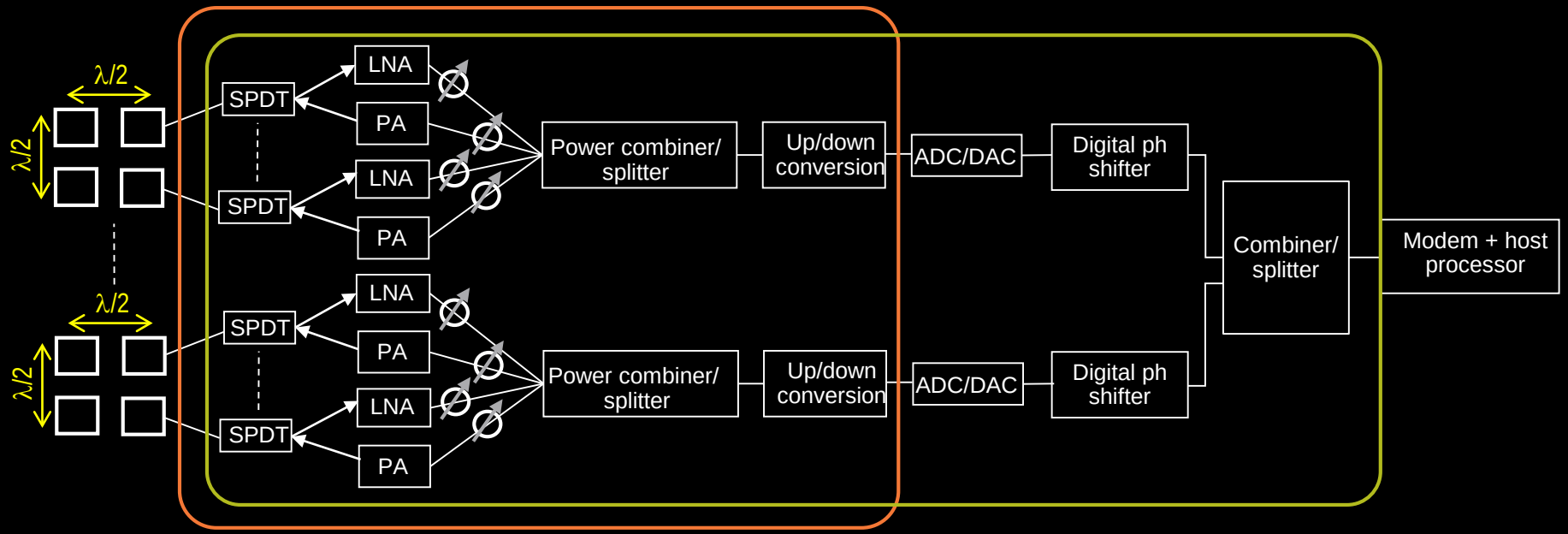
5G/mmWave operation adds another dimension to both raw RF performance extraction and physical limitations

PA/transmitter efficiency is paramount in managing UE battery power for small arrays and thermal reliability for large arrays



Source: "E. McCune, Eridan Communications, "Fundamentals for Energy-Efficient Massive MIMO, IEEE Wireless Communications and Networking Conference 2017""

Paving the way to 5G/mmWave: 45RFSOI & 22FDX®



FEM-Centric Designs: Highest performance with architecture flexibility

45RFSOI*

- High Ft / Fmax
- Hi-Res substrate for high power handling (>25 dBm) and low loss
- Low-loss BEOL
- Low density, medium leakage logic

5G

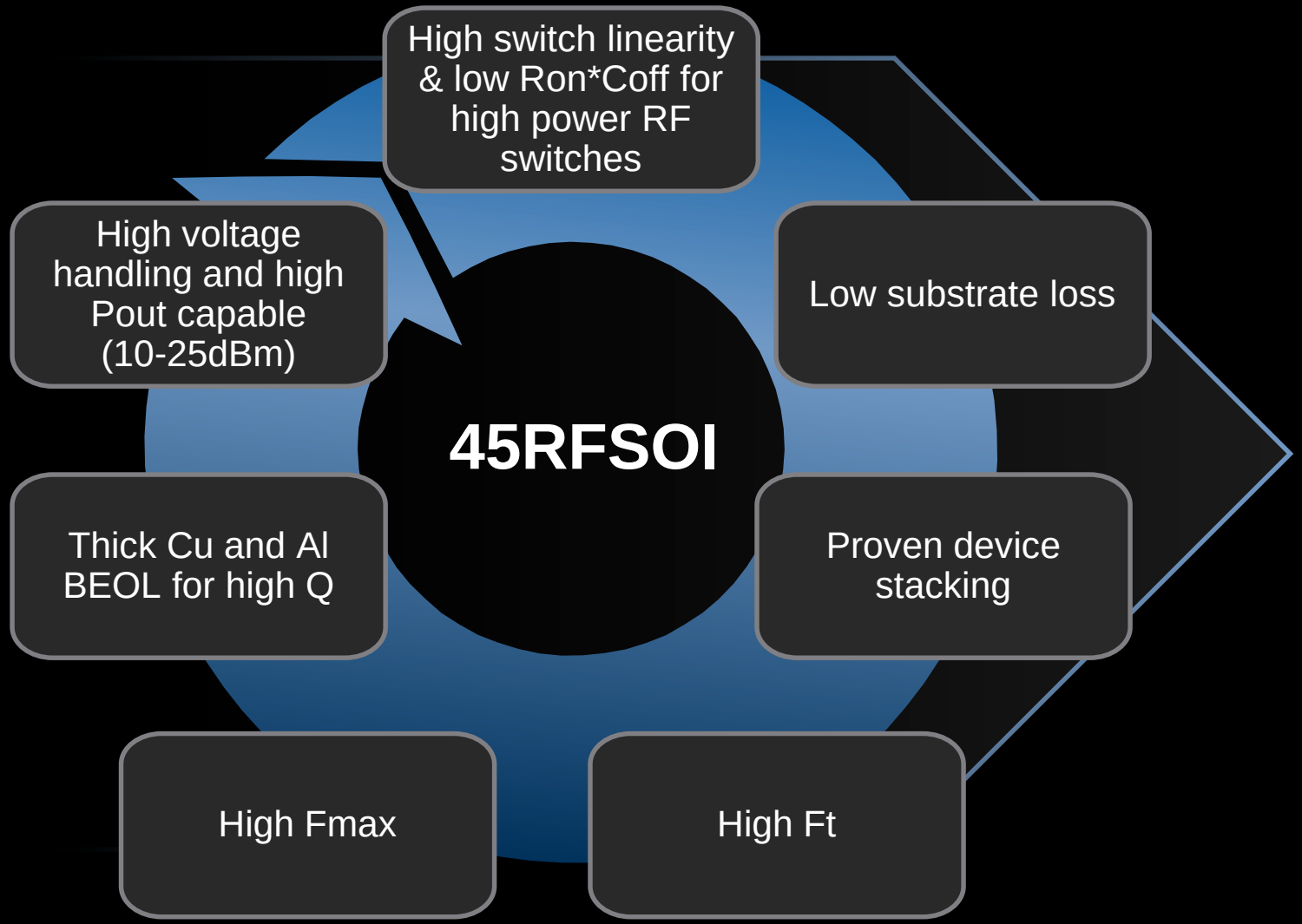
Integration-Centric Designs : Lowest system cost and lowest power consumption

22FDX

- Highest Ft / Fmax & highest GM/I
- Low-loss BEOL
- Lowest power and highest density logic

*SiGe also possible for >+25dBm

45RFSOI technology advantage



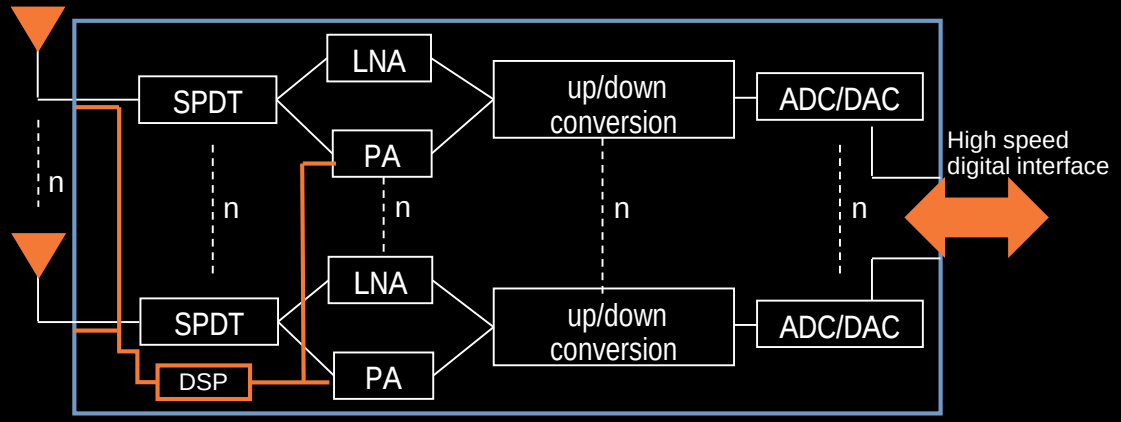
Ideal for beamforming FEMs (switches, LNAs, PAs)

mmWave SoCs: 22FDX® for next-gen mmWave digital beamforming

22FDX/12FDX is an ideal technology for low power RF SOCs with extensions for mmWave digital beamforming:

- Ft/Fmax (350 GHz / 430 GHz)
- Very low FD-SOI FET capacitance for ultra broadband mmWave
- Stacked SOI FETs for high Pout/PAE PA , switch, LNA integration with TRX; ultra low PA self heating (20 nm BOX)
- Back gate knob for performance tuning over temp, process
  - Allows wide V_{th} adjustment to calibrate PVT variations
  - Can be used to dial RF performance up or down depending on use conditions
- Ultra low power and area ADC (<10fJ/conv) and DAC
- High density (>5M gates/mm^2) high performance, ultra low power DSP (for digital filtering and high speed SERDES)

Single chip solution:
28-40 GHz 5G digital beamforming TRX with integrated FEM



Summary and conclusion

- 5G is on the tactical horizon with deployments being accelerated….significant announcements made bringing 5G closer to reality
- 5G NR spec driving increased complexity in radio hardware to support 5G, and for backwards compatibility without degrading 4G/LTE performance
- This complexity is being compounded by more stringent RF performance requirements
- Significant growth in RF FEM SOI content is anticipated due to the architectural complexities and performance requirements needed to address 4G and 5G NR coexistence
- GF has a rich portfolio of SOI offerings that align well with proposed architectures and continue to advance in order to meet the challenges of 5G NR requirements

Thank you

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