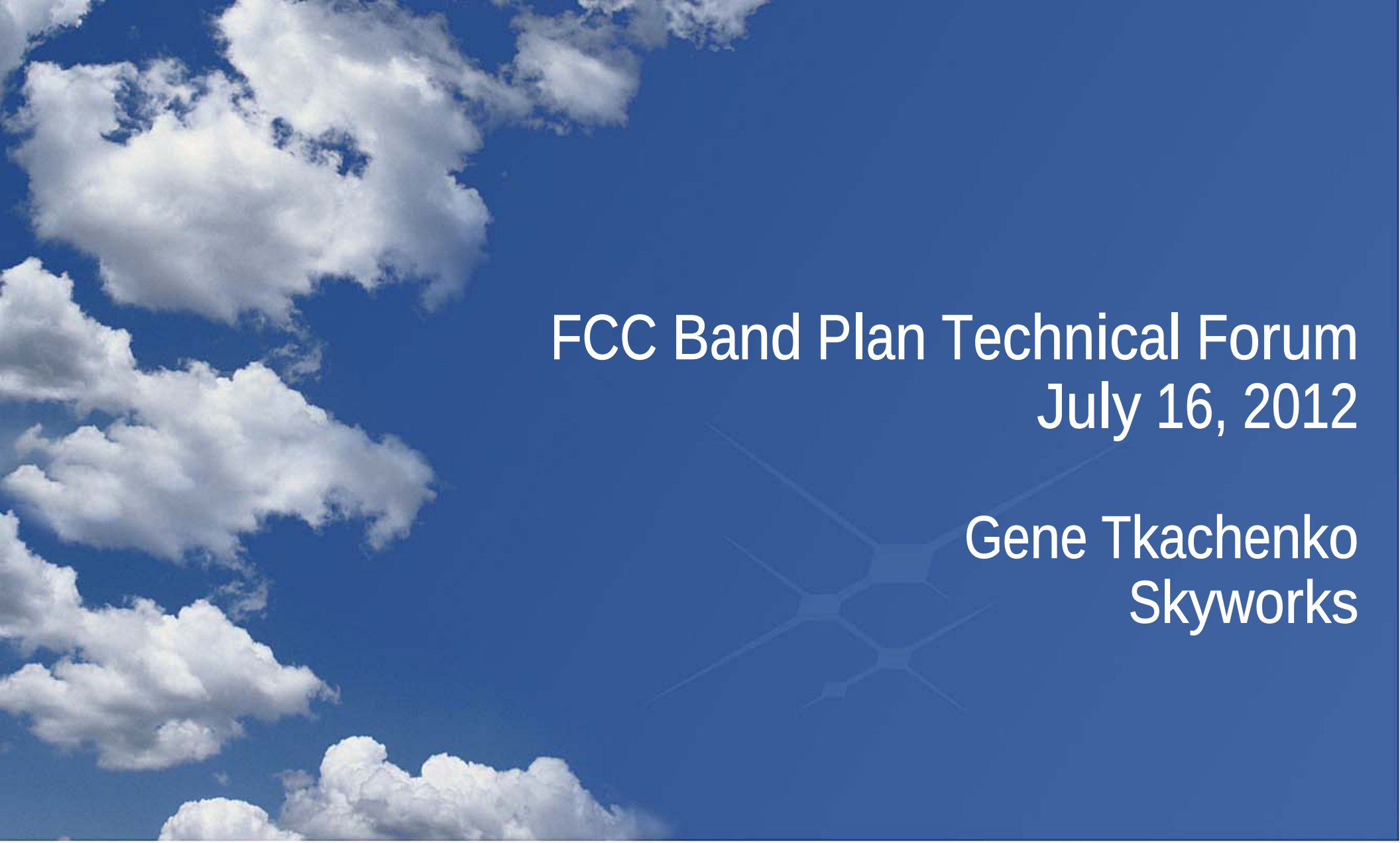
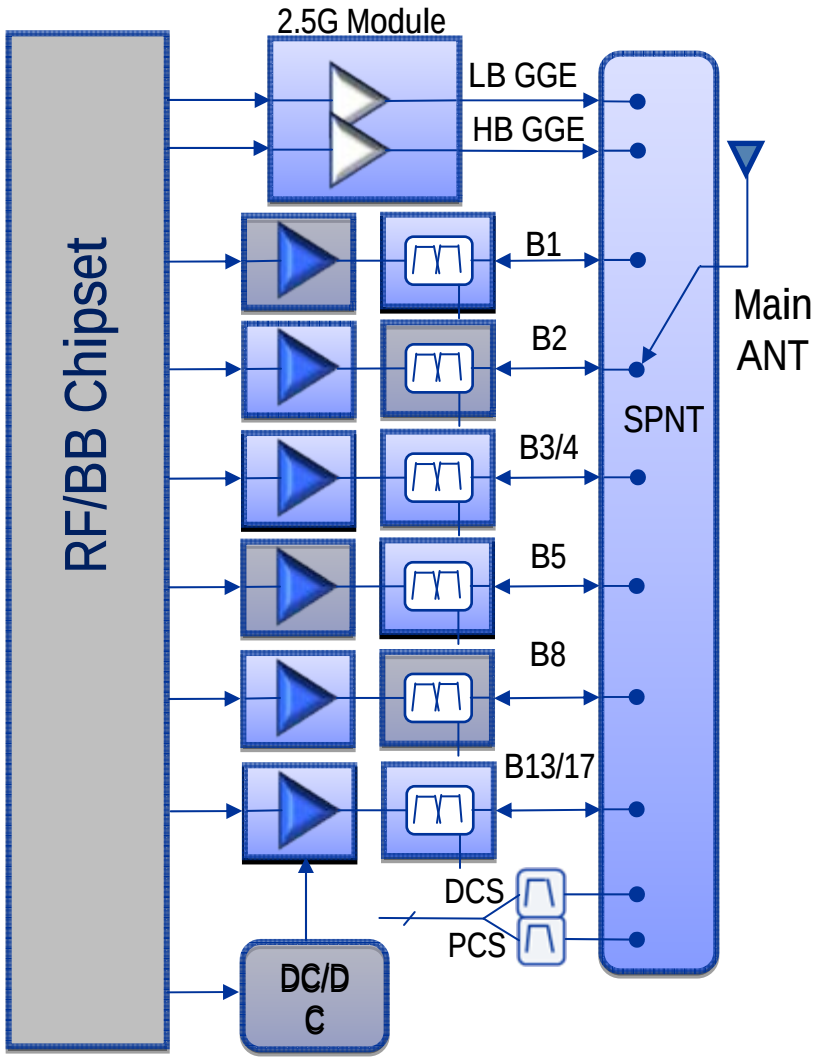


FCC Band Plan Technical Forum
July 16, 2012

Gene Tkachenko
Skyworks

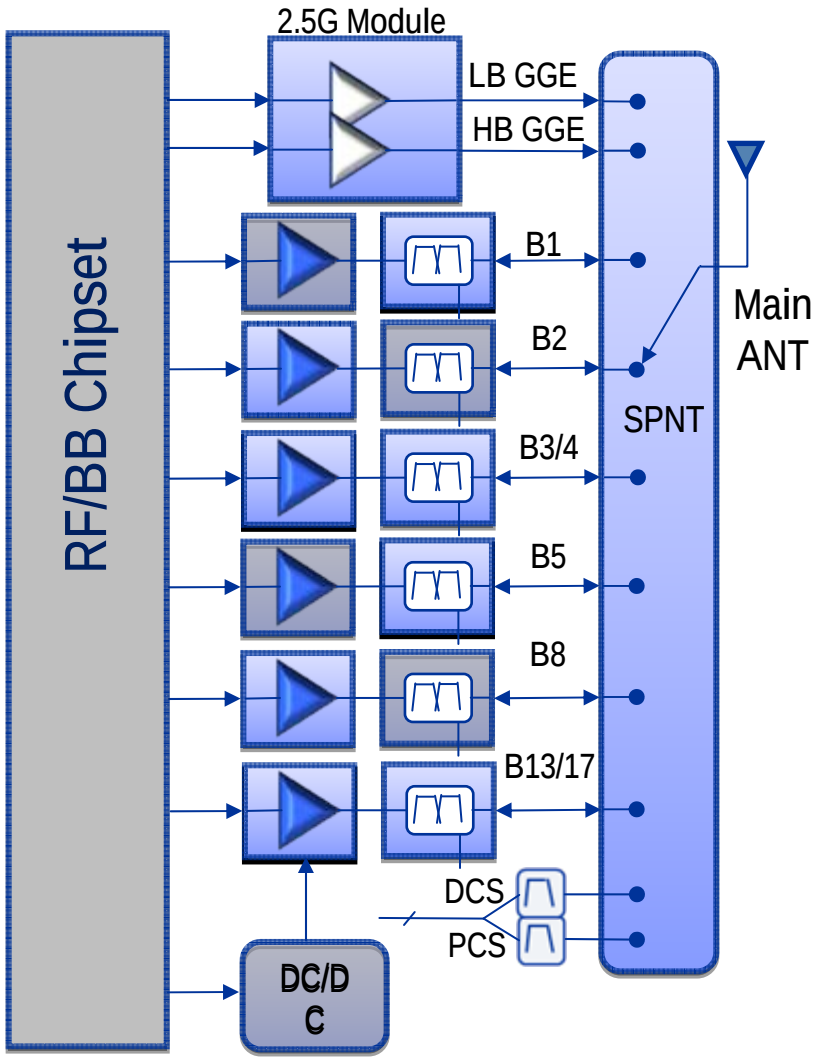
SKYWORKS®
BREAKTHROUGH SIMPLICITY

Typical Smartphone RF Front End Today



- Quad Band GPRS/EDGE Module
- 5 WCDMA Bands
- 1 LTE Band
- SP12T Antenna Switch

Typical Smartphone RF Front End Today



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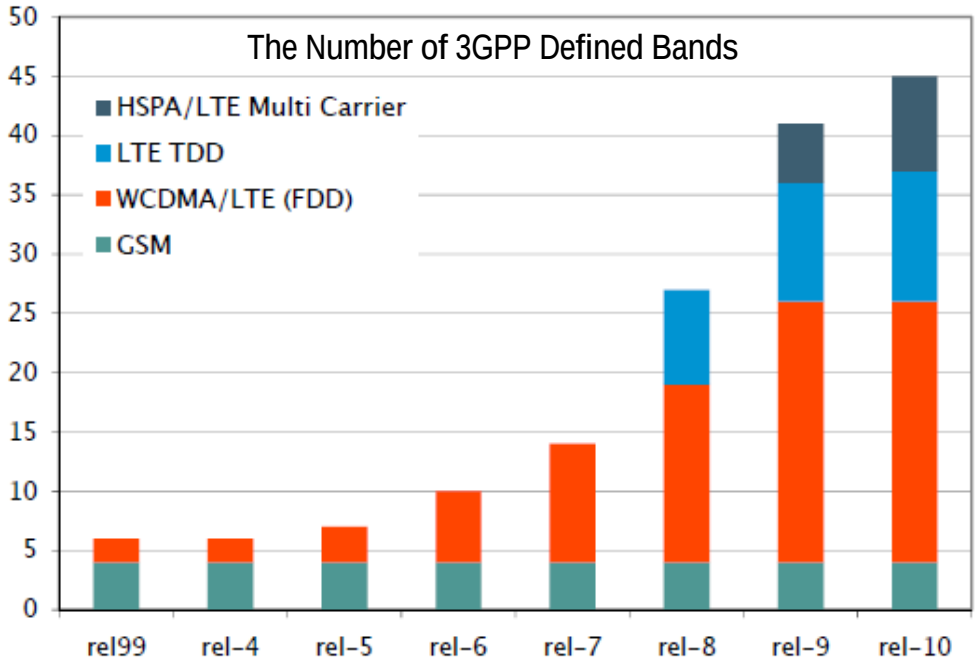
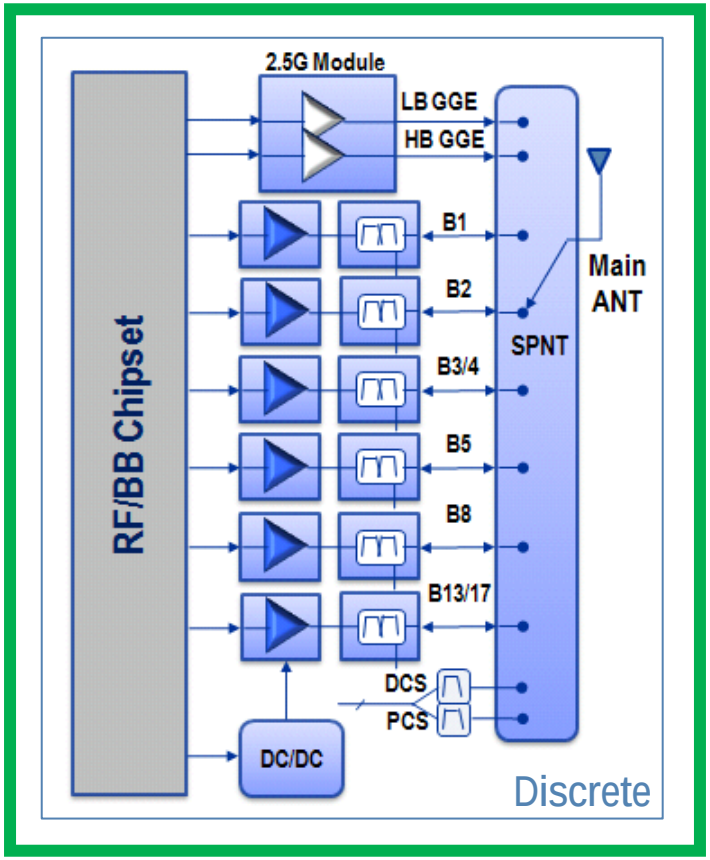


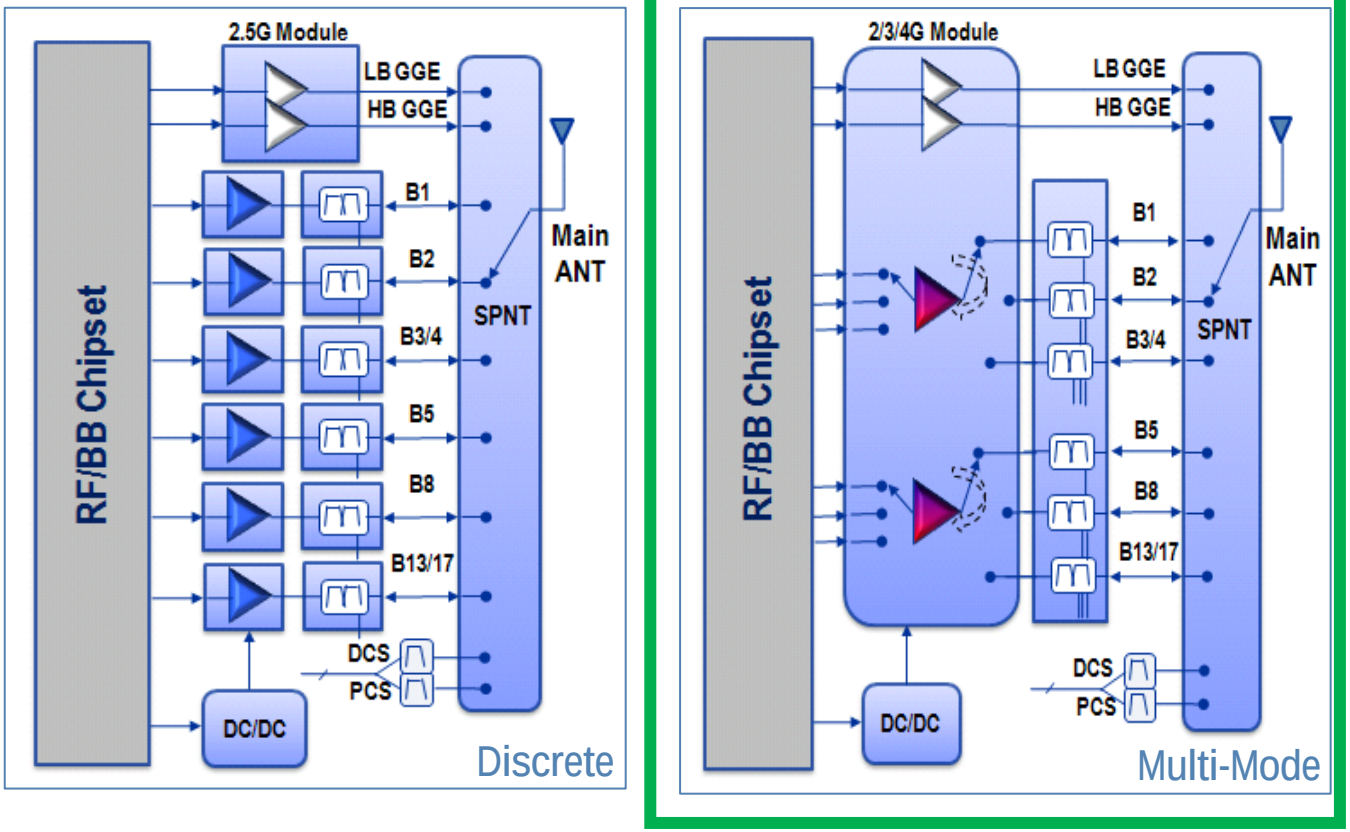
How to handle all these additional bands?

The Answer is Integration and Multi-Mode/Band



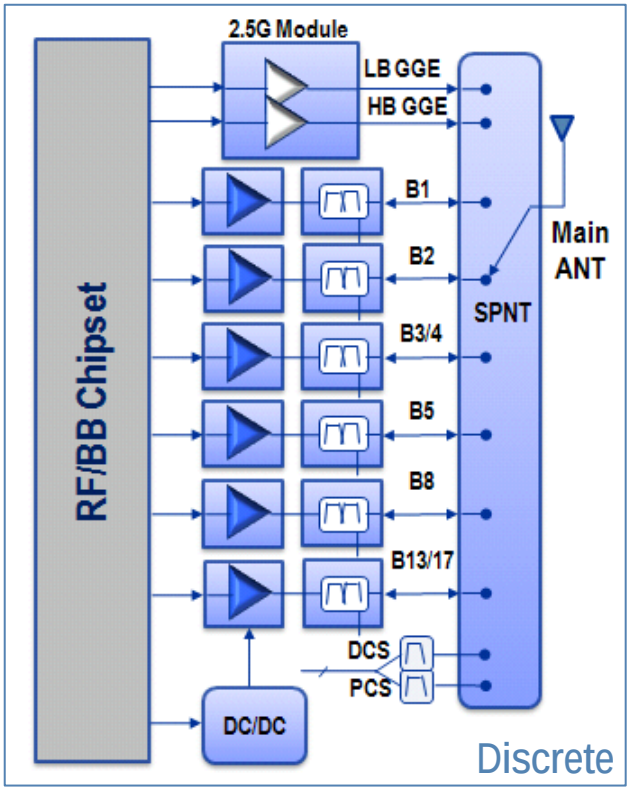
- Discrete architecture allows narrow-band RF optimization in every band and is flexible
- However it takes up A LOT of valuable smartphone real estate and is costly
- One PA per Band – Not a viable solution for future smartphones with more bands

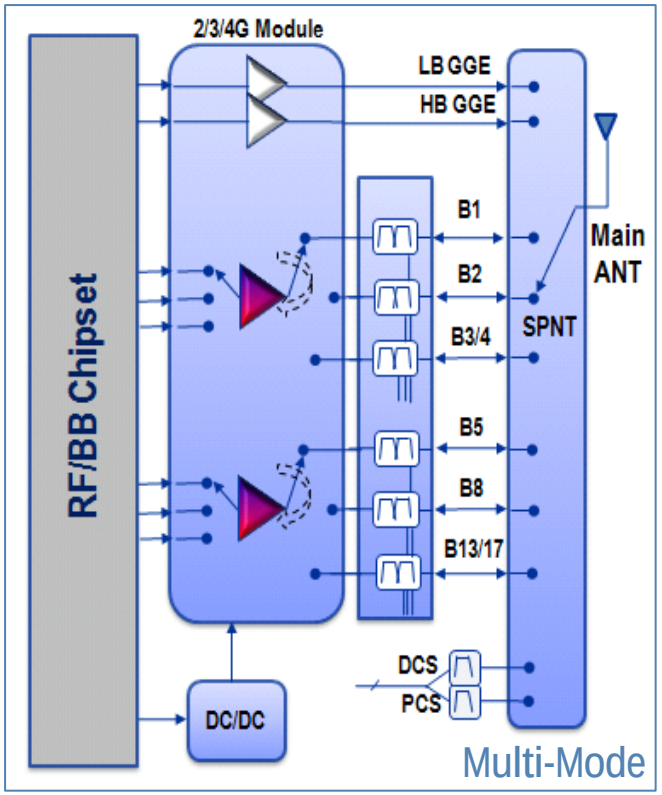
The Answer is Integration and Multi-Mode/Band

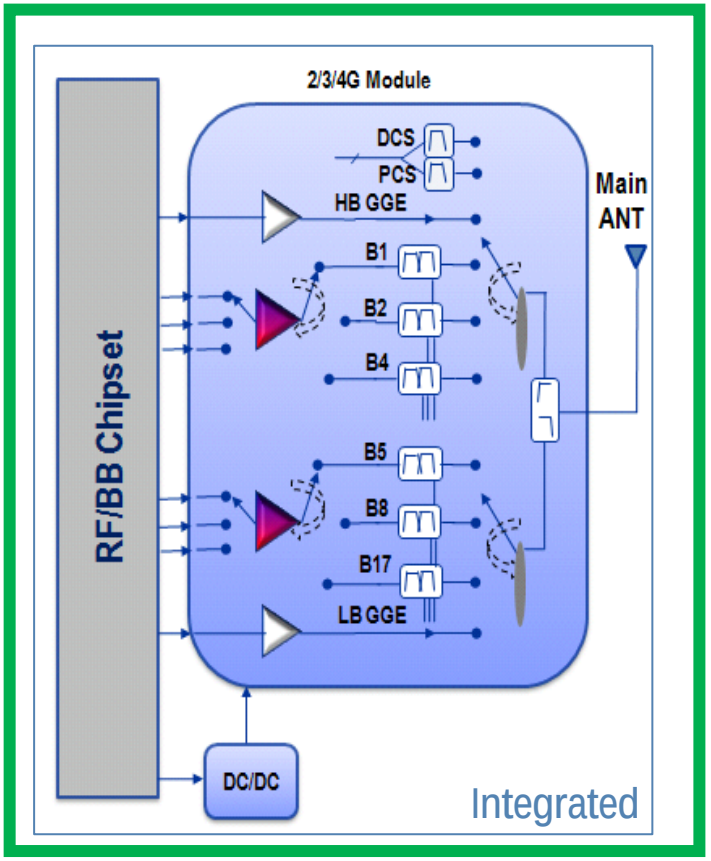


- Multi-mode supports broad-band operation from a single 3/4G or 2/3/4G PA
- Scalable: E.g. B5 PA now supports also B8, also B20, B26, and then B13 and B17
- Flexibility with supporting external “add-on” band PA’s, e.g. B7

The Answer is Integration and Multi-Mode/Band



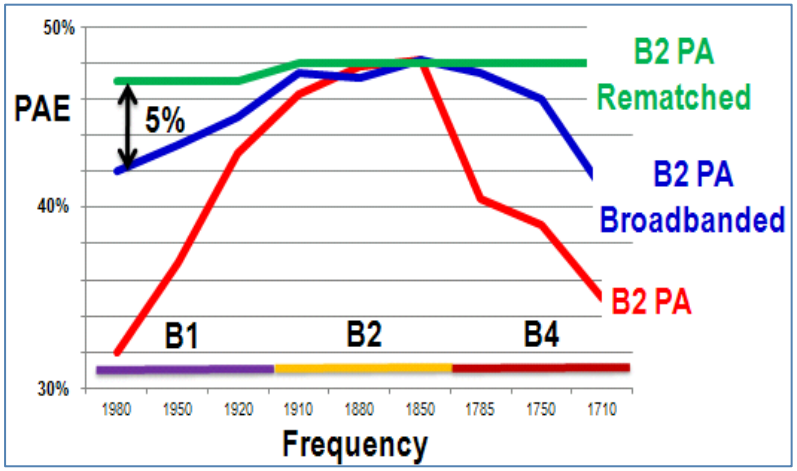


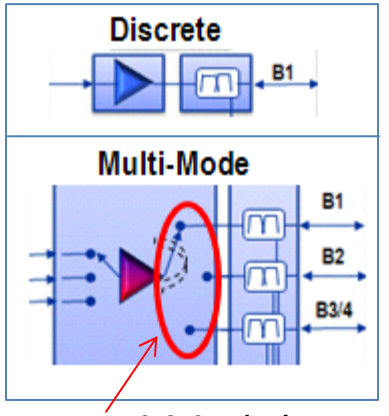


- More integration allows improved performance per Band via optimization of the PA-Filter, Switch-Filter, PA-Switch interfaces, not necessarily in the 50 Ohm environment
- Significantly cuts down the overall phone board footprint
- Can also support external “add-on” band PA’s, e.g. B7

Challenges from Adding Extra Bands

- Maintaining Linear Efficiency of the PA
  - Current consumption while meeting ACPR/EVM
    - → Battery Life and Heat (User Experience!)
  - More difficult with higher Peak-to-Average Signals
    - → HSUPA→LTE→ LTE-Advanced
  - More difficult when broadband operation with the same PA supporting more bands is required
    - ~3-5% PAE loss due to broadbanding (PA matching trade-off)
    - ~3-5% PAE loss vs. discrete due to losses of the extra band switch
  - PA will likely have to deliver higher power (band specific)
  - Adding each extra band adds an extra throw for the band and antenna switch
  - Difficult Duplexer spec or extra notch/coexistence filter will also add losses
- Inter-operability, co-existence – PA can't pollute other bands
  - Self-desense of own receiver, GPS, WiFi, jamming other UE → noise, IMD, harmonic requirements





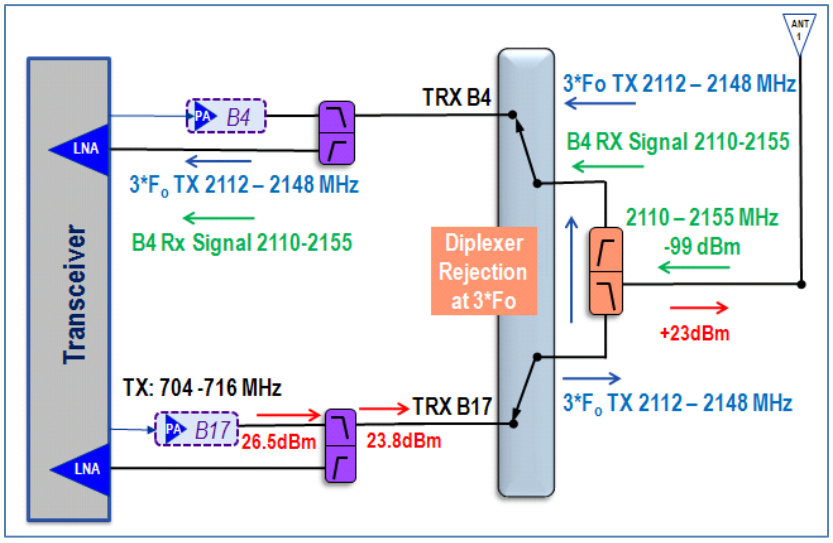
Extra 0.3-0.5dB loss

Examples of Carrier Aggregation Challenges

- $2*F_o$ and $3*F_o$ falling in opposite Rx Band
  - Band 4 and Band 17 CA → $3*F_o$ Band 17 = Band 4 Rx
    - Band 3 and Band 8 CA → $2*F_o$ Band 8 = Band 3 Rx
    - Band 7 and Band 8 CA → $3*F_o$ Band 8 = Band 7 Rx
- Forces tough front-end requirements
  - Switch Linearity and Diplexer linearity as low as -130dBc
  - Diplexer attenuation of 35dB or more, DPLX $3*F_o$ rejection
  - PA harmonic specs as low as -50dBm/MHz
  - Passive components (filters) also have to be linear enough
  - Multiple sources of coupling – tougher isolation specs
- These could be 10-20dB tougher than current performance
- Frequently no degradation in performance is demanded!
  (even though we are adding filtering, notching, etc and every 0.1dB counts)

CA band or band combination	Operator	3GPP E-UTRA bands	Duplex mode
Band 4 + band 17	AT&T	Band 4: 1710 – 1785 MHz (UL) 2110 – 2155 MHz (DL) Band 17: 704 – 716 MHz (UL) 734 – 746 MHz (DL)	FDD
Band 2 + band 17	AT&T	Band 2: 1850 – 1910 MHz (UL) 1930 – 1990 MHz (DL) Band 17: 704 – 716 MHz (UL) 734 – 746 MHz (DL)	FDD
⋮	⋮	⋮	
Band 5 + band 12	US Cellular	Band 5: 824 – 849 MHz (UL) 869 – 894 MHz (DL) Band 12: 699 – 716 MHz (UL) 729 – 746 MHz (DL)	FDD
Band 4 + band 13	Verizon	Band 4: 1710 – 1785 MHz (UL) 2110 – 2155 MHz (DL) Band 13: 777 – 787 MHz (UL) 746 – 756 MHz (DL)	FDD

Table 2. *CA band or band combination.*



Upcoming Innovation Examples

- Integrated solutions:
  - SkyOne™ platform
- Smart/Adaptable PA's/FEM's
  - Envelope Tracking, Digital Pre-Distortion, Doherty…
  - Programmability, reconfigurability in the RF front end, e.g. MIPI RFFE, ANT Couplers, Tuners, Feedback Receivers and control loops sensing power, VSWR and adapting ANT/PA matching, biasing, etc
- Fundamental Device Technology Work
  - Best PA technology – GaAs: concurrently engineered circuit, unit cell and even epi profile. Fundamentally ~10% better unit cell PAE than Si
  - Harmonically tuned classes of operation (e.g. Class J, inverse Class E, Hybrid Class B/J*, etc)