TOWERJAZZ

The Global Specialty Foundry Leader

5G Opportunity

August 2019

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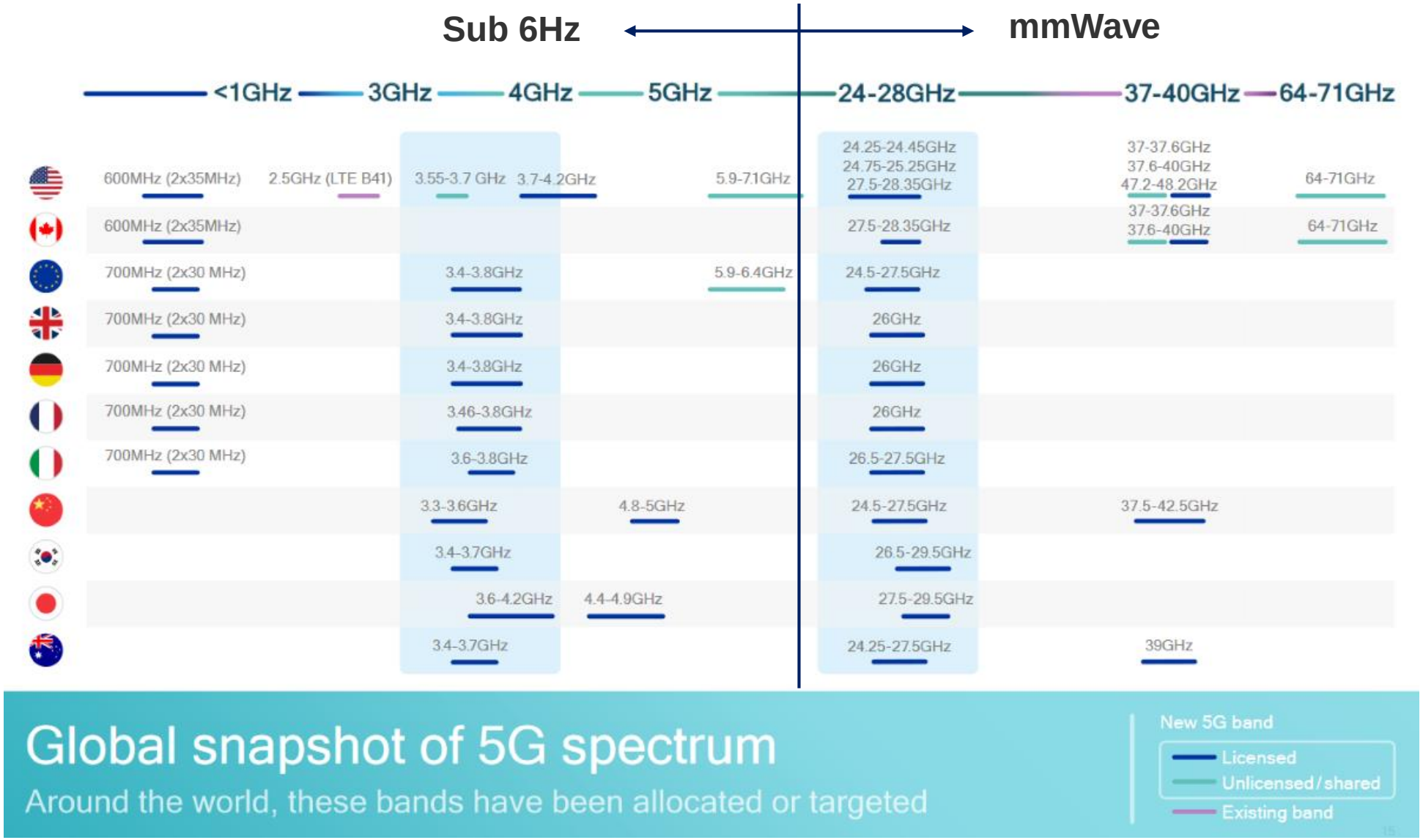
5G Wireless vs. 4G

5G Wireless is designed to support higher data rates through

- Use of more frequency bands to carry more data through “carrier aggregation”
- Use of much higher frequencies that have more “capacity” (mmWave 5G)
- MIMO (multi-in-multi-out): multiple antennas each capable of transmit/receive

5G Frequency Bands



5G Wireless vs. 4G

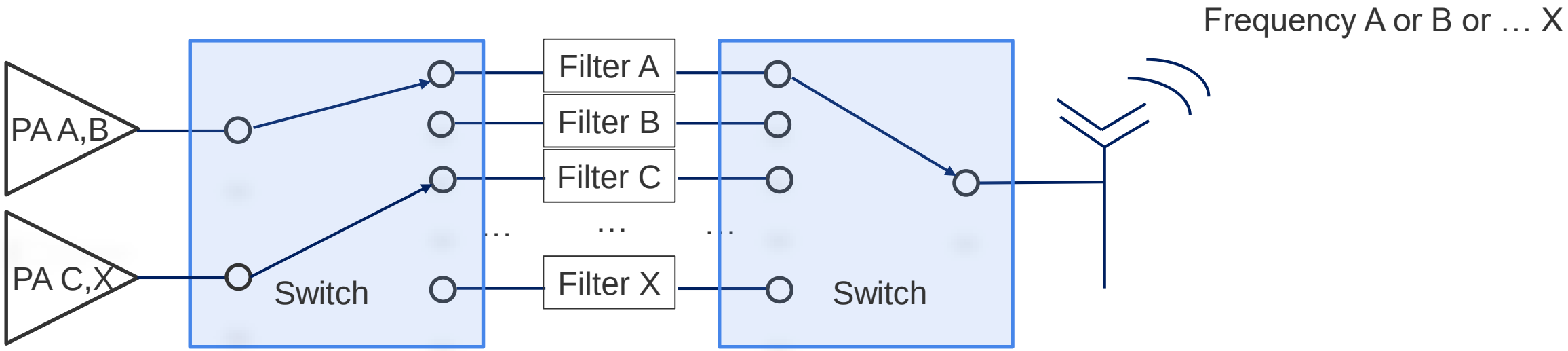
Implications on RF market:

1. **Sub 6Hz**: more RF content in handsets to support more frequency bands and antennas
2. **mmWave**: technology shifts to support frequencies that are 10x higher than today
3. **Infrastructure**: base-stations, small cells, faster optical fiber connections to the network

Industry expectation: 5G at <1% of handsets in ‘19 and ~25% in ‘23

Sub 6GHz 5G

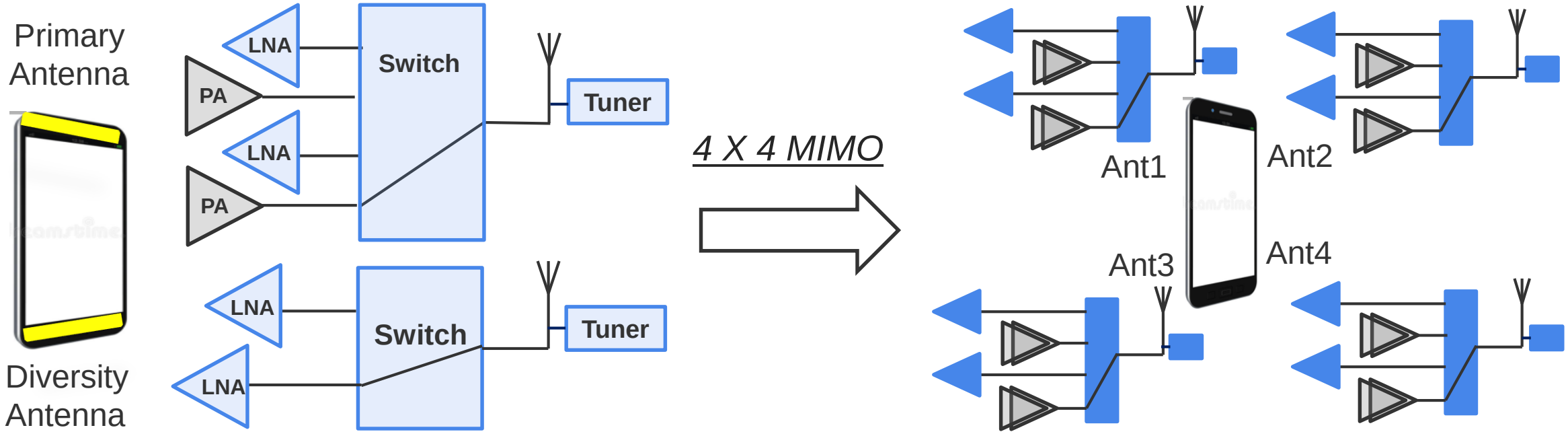
- Impact of more frequency bands on RF content in handsets
  - Switches are used to select filters and bands -> more frequency bands imply more switches
  - In addition, more PAs and LNAs may be required to cover frequency bands that are widely separated



- Technology: 5G RF switches in handsets are generally built in high-end RF SOI technology

Sub 6GHz 5G

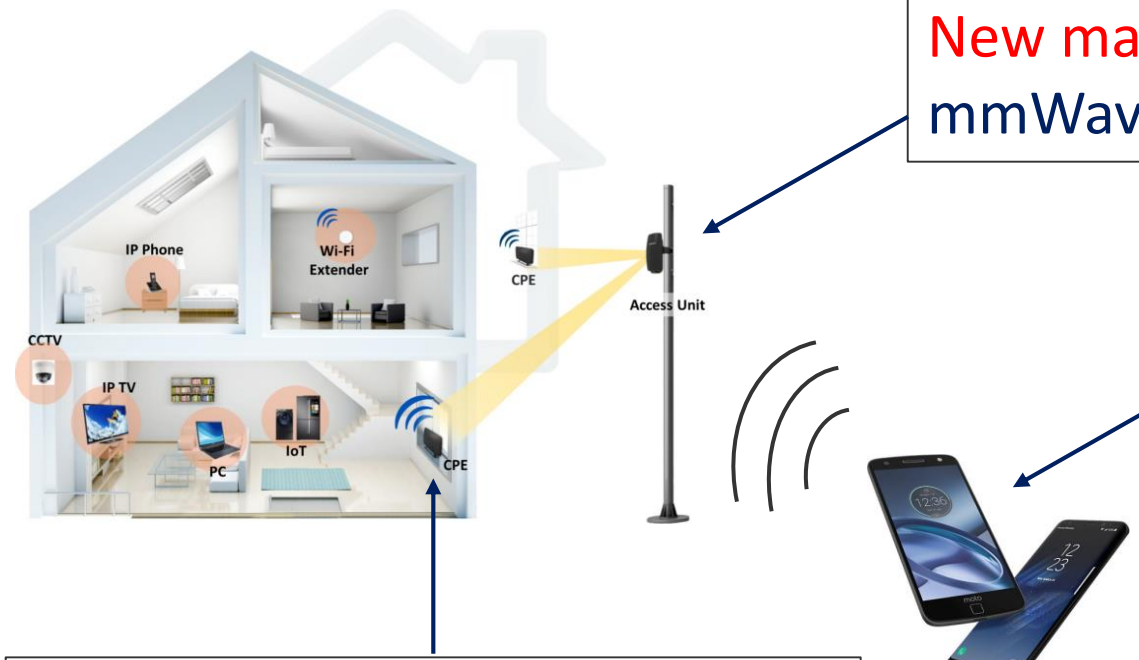
- Impact of more antennas on RF content in handsets
  - Each antenna requires a low-noise-amplifier (LNA) and in some cases a power amplifier (PA)
  - Increasingly each antenna requires an Antenna Tuner to support the wide range of 5G frequencies



- Technology: SiGe and RF SOI for LNA; RF SOI and in the future RF MEMS for antenna tuning

mmWave 5G: New Large Potential Market for Silicon-base RF

Small-cell fixed wireless access points can provide “last mile” broadband distribution and fast data to handsets in range creating a large new potential market for Silicon-based RF



New market for RF for fixed-wireless base-station mmWave infrastructure over the next several years

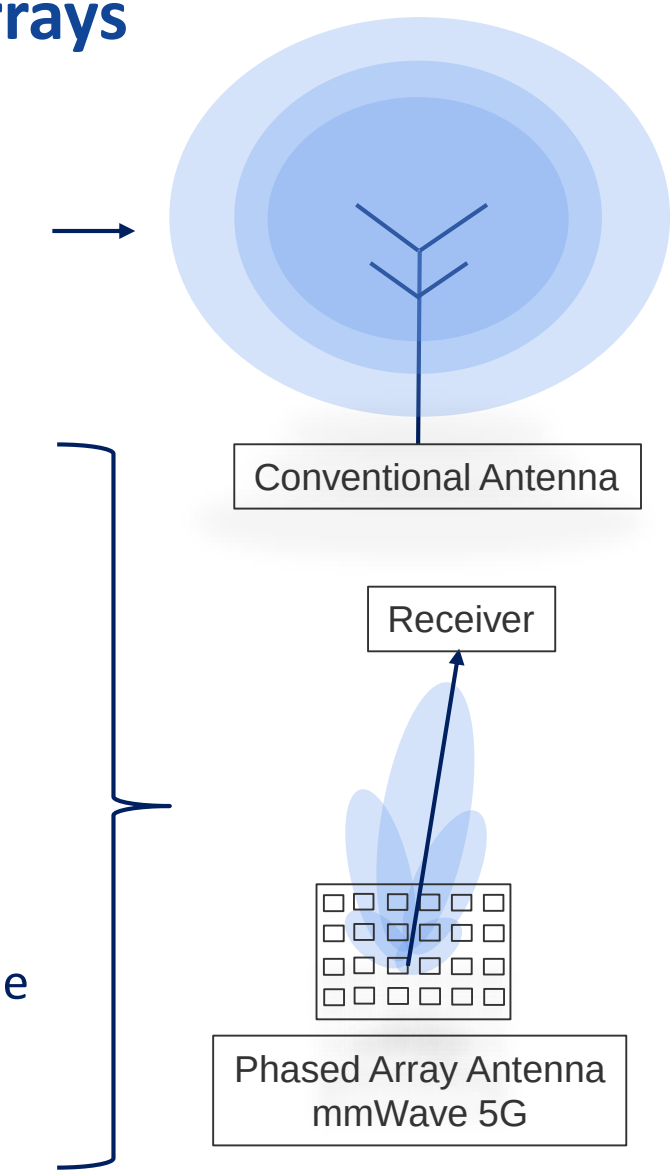
Additional content in handsets to support mmWave with Phased Array Power Amplifier -> enabling Si-based Power Amplifiers vs. III-V based PAs used for sub 6GHz

New market for 5G mmWave gateway for home/office

mmWave 5G: Power Amplifiers in Silicon with Phased Arrays

- Today's antennas distribute power uniformly requiring high-power PAs built in III-V semiconductors since most of the power is wasted and little is received

- At mmWave frequencies it becomes more efficient to create an array of small power amplifiers and antennas that combine to direct power toward the receiver so less power is wasted
- The lower power levels and high-level of integration required for phase array transmitters make Silicon the better technology (SiGe or RF SOI)
- Devices will require multiple antennas for 360-degree coverage and each antenna will require a large number of amplifiers powering each element in the array potentially creating a new, large market for Silicon-based RF technology

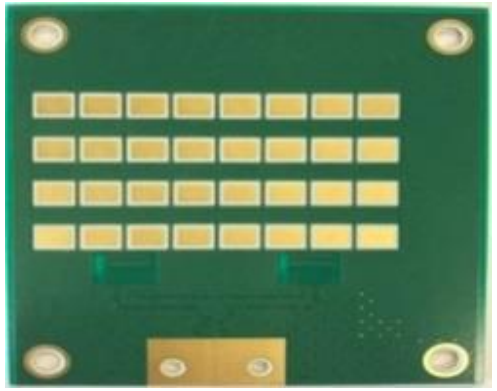


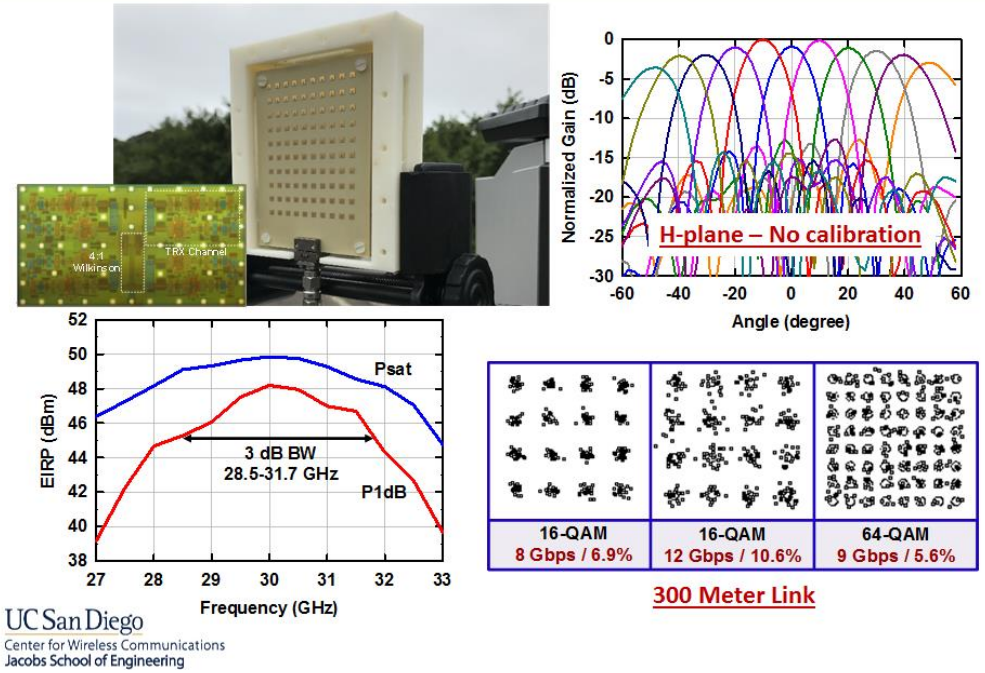
TowerJazz SiGe Full 5G 28GHz Transmit-Receive 12 Gbps Chipset

Press Release: UCSD and TowerJazz Demonstrate Best in Class 5G Mobile Transmit-Receive Chips with Greater than 12 Gbps Data Rates

Design targets FCC plans for licensing 28GHz communications band

Phased array technology available now to meet emerging billion dollar 5G markets





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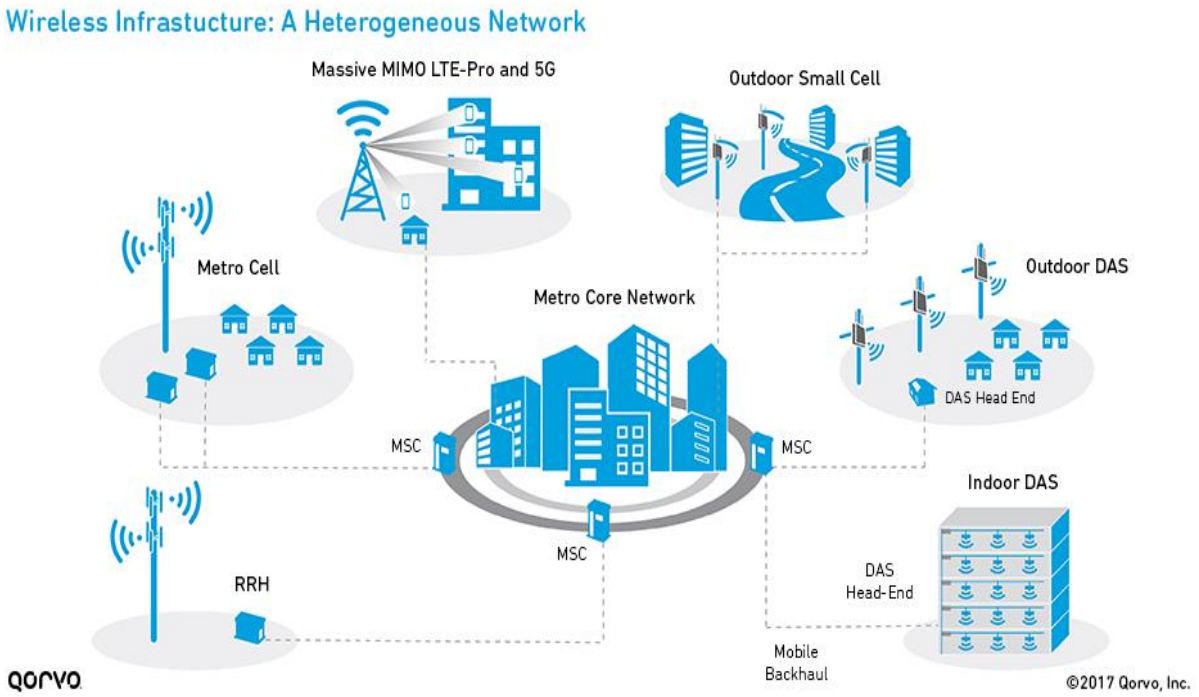
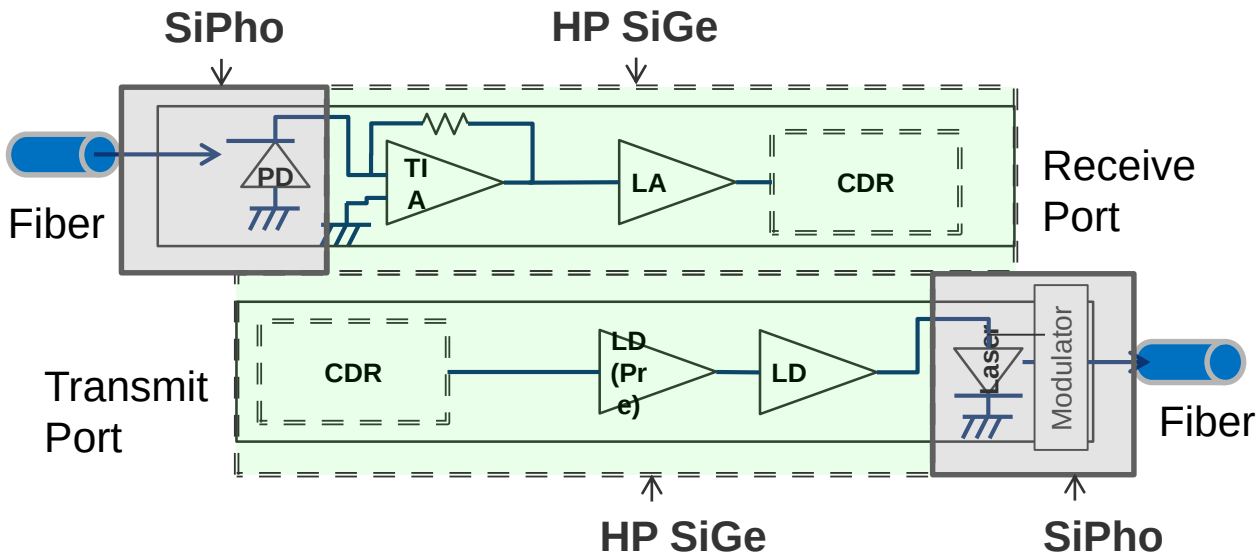
5G Infrastructure





- Optical fiber is likely to dominate transport from base-stations and small-cells into the network
- 5G increases the number of connections and also the speed (moving from 10Gb/s to 25Gb/s)
- Technology of choice is SiGe (TowerJazz holds >60% market share in this market)
- Silicon photonics is expected to also play a part in this market in years to come

Summary of the 5G Opportunity

1. **Sub 6Hz**
    1. More RF content in handsets to support more frequency bands and more antennas
    2. For TowerJazz this creates growth opportunity for RF SOI (Switch/Tuners) and SiGe (LNA)
    3. Longer term RF MEMS can play a role (TowerJazz has a strong presence in the RF MEMS area)
2. **mmWave**
    1. New RF market both for small-cell basestations, gateways, and handsets
    2. For TowerJazz it also creates an opportunity to participate in the power amplifier market with SOI/SiGe as power amplifiers migrate to phased-array architectures in silicon-based technology
3. **Infrastructure**
    1. Upgrade to base-stations and optical fiber to support 5G traffic
    2. For TowerJazz this creates a growth opportunity for optical SiGe for which we have a high market share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