emcore®

Mixed-Signal Optics

Analog Fiber Optics and 5G

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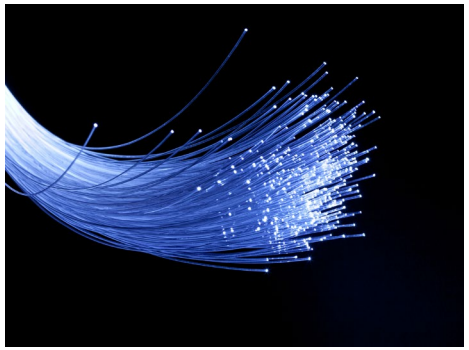
Fiber Optics

Fiber Optics 101:

A laser converts an electric signal into an optical signal; a photodiode converts the optical signal back into an electrical signal

Fiber-optic Cable vs. Coaxial Cable

- **Speed:**
  - Fiber-optic cable is much faster
  - Light vs. electricity
- **Distance:**
  - Fiber-optic cable has much less signal loss and attenuation
  - Coaxial cable is limited at 500m, while fiber-optic cable can be used for transmission up to 100 kms without a booster

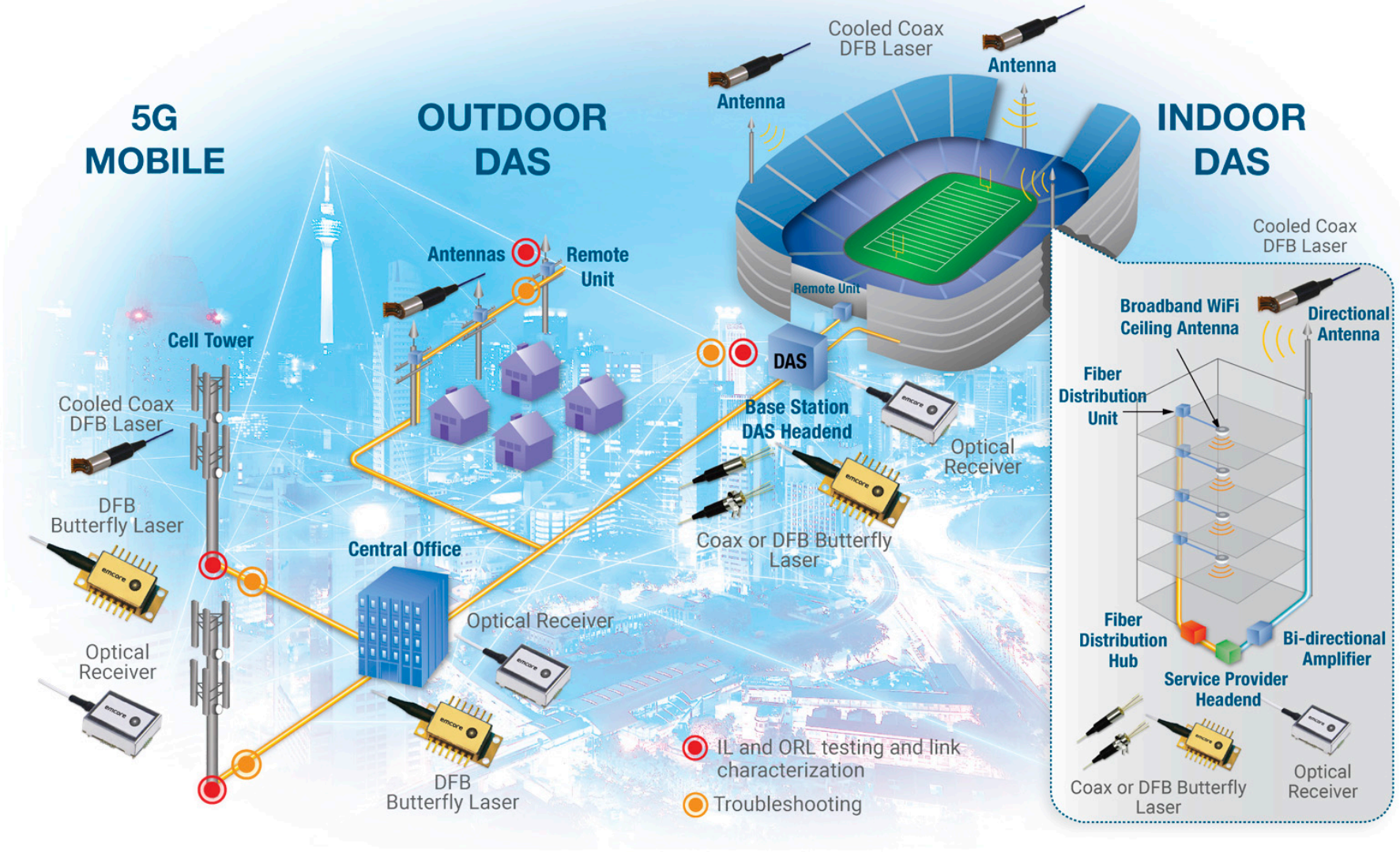


Analog vs Digital Fiber Optics

- **Number of Fibers:**
  - Analog fiber optics usually uses one piece of fiber
  - Digital fiber optics usually uses multiple pieces of fiber for simultaneous transmission
- **Input Signal:**
  - Analog fiber optics takes a modulated analog signal (OFDM) as a input and transmits the data as light. OFDM data is what is transmitted wirelessly in the air. Speed is determined by frequency and bandwidth. 5G mid-band goes up to 6GHz, and high-band starts at 24GHz
  - Digital fiber optics takes digital signal (0s and 1s) and transmits the data light. Since all signals in nature are analog, the signal has to be converted to digital before it can be transmitted. Speed is measured by gbps.
- **Speed/Capacity:**
  - Analog fiber optics: speed is determined by frequency and bandwidth. 5G mid-band goes up to 6GHz, and high-band starts at 24GHz
  - Digital fiber optics: speed is measured by gbps.
- **Performance Parameters:**
  - Analog fiber optics: linearity
  - Digital fiber optics: latency, jitter, synchronization

Analog Fiber Optics for 5G DAS

Some DAS systems are analog, and some are digital, in terms of fiber optics



Analog Fiber Optics for 5G DAS

- **EMCORE analog lasers and photodiodes are deployed in DAS systems around the world**
  - Stadiums, airports, campuses
- **Lasers need to go up to 6GHz for 5G DAS**

- **Levi Stadium, Santa Clara, CA**

- **U.S. Bank Stadium, Minneapolis, MN**

- **Apple Park, Cupertino, CA**

EMCORE's Solution for 5G DAS

1998 laser:

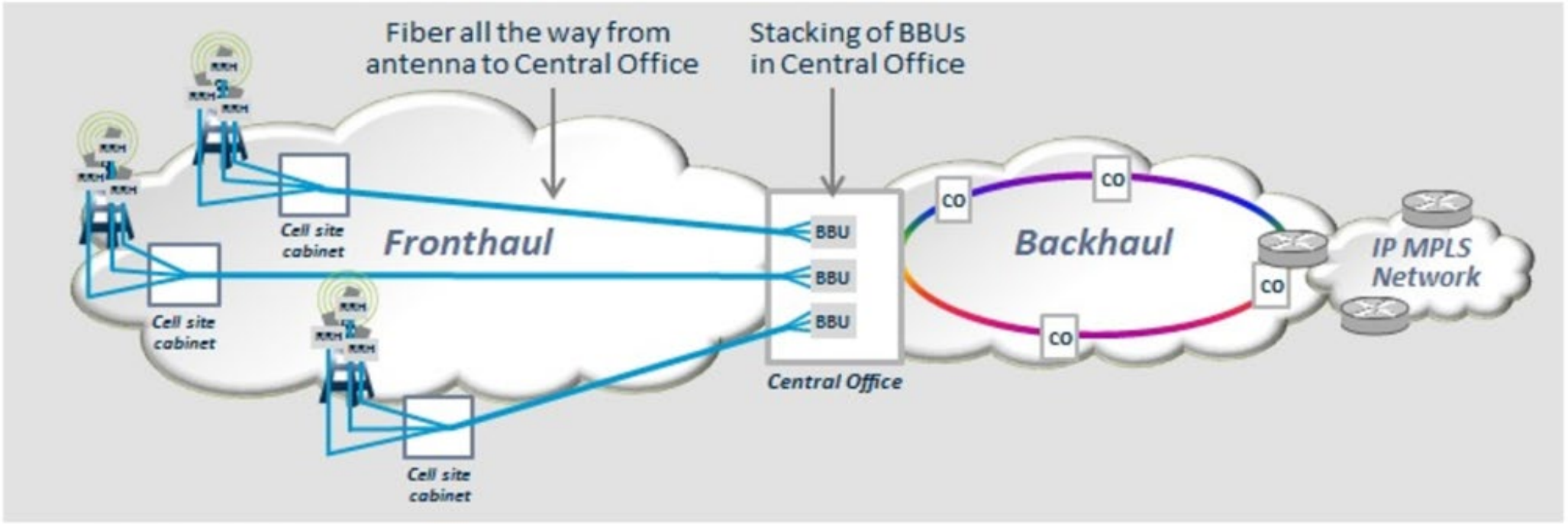
- High linearity
- Output power > 10 dBm
- Bandwidth > 6 GHz
- Cooled / Temperature Controlled

Next wireless for the U.S. Market needs the CBRS band from 3.55GHz to 3.7GHz!!!

NEW

Performance Highlights	
Parameter	**Typical Value**
Optical Output Power	10 dBm
IIP3 (at 2.9GHz)	70 dBm
Noise Figure	44 dB
Relative Intensity Noise (at 6 GHz)	-158 dB/Hz
Laser Linewidth	5 MHz
S21 Flatness (Peak-Peak)	1.5 dB

Analog Fiber Optics for 5G Base Station

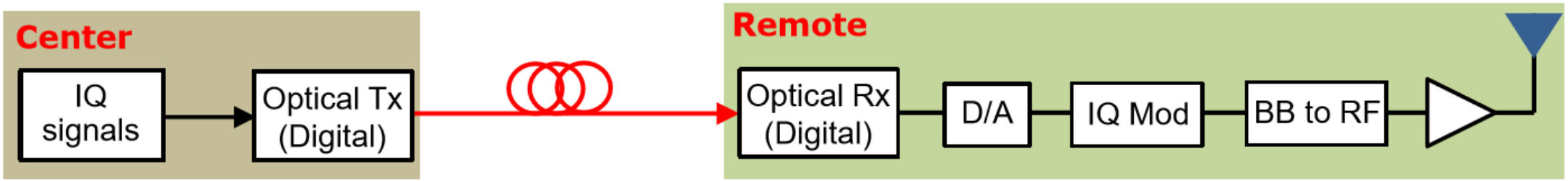


RRH: Remote Radio Head
BBU: Base Band Unit

- **5G Wireless Fronthaul Features and Characteristics**
  - Higher frequency/speed, and more radio access points
  - BBUs are moved away from the RRH and to a centralized location, combining the previous CPRI fronthaul and Ethernet mid-haul
  - Increased number of MIMO arrays on the cell towers
  - **The 5G network longs for a resolution for RE with smaller size, lighter weight and lower power consumption!**

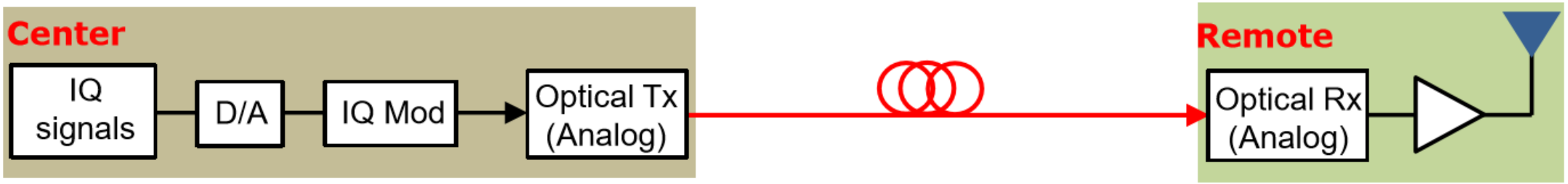
Analog Fiber Optics for 5G Base Station

Digital Fronthaul Transmission (4G Network)



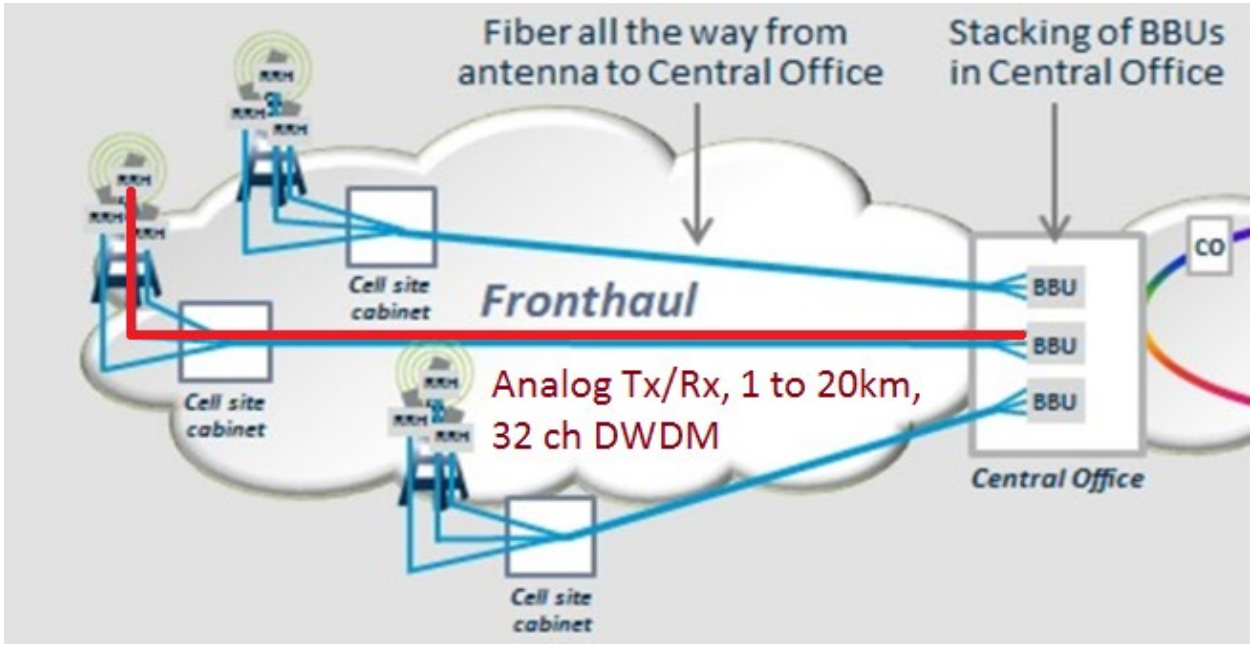
- Long latency; synchronization and jitter issues; high speed D/A (high cost); high power and weight at RRH

Analog Fronthaul Transmission (eliminate down conversion, demodulation and A/D at RRH)



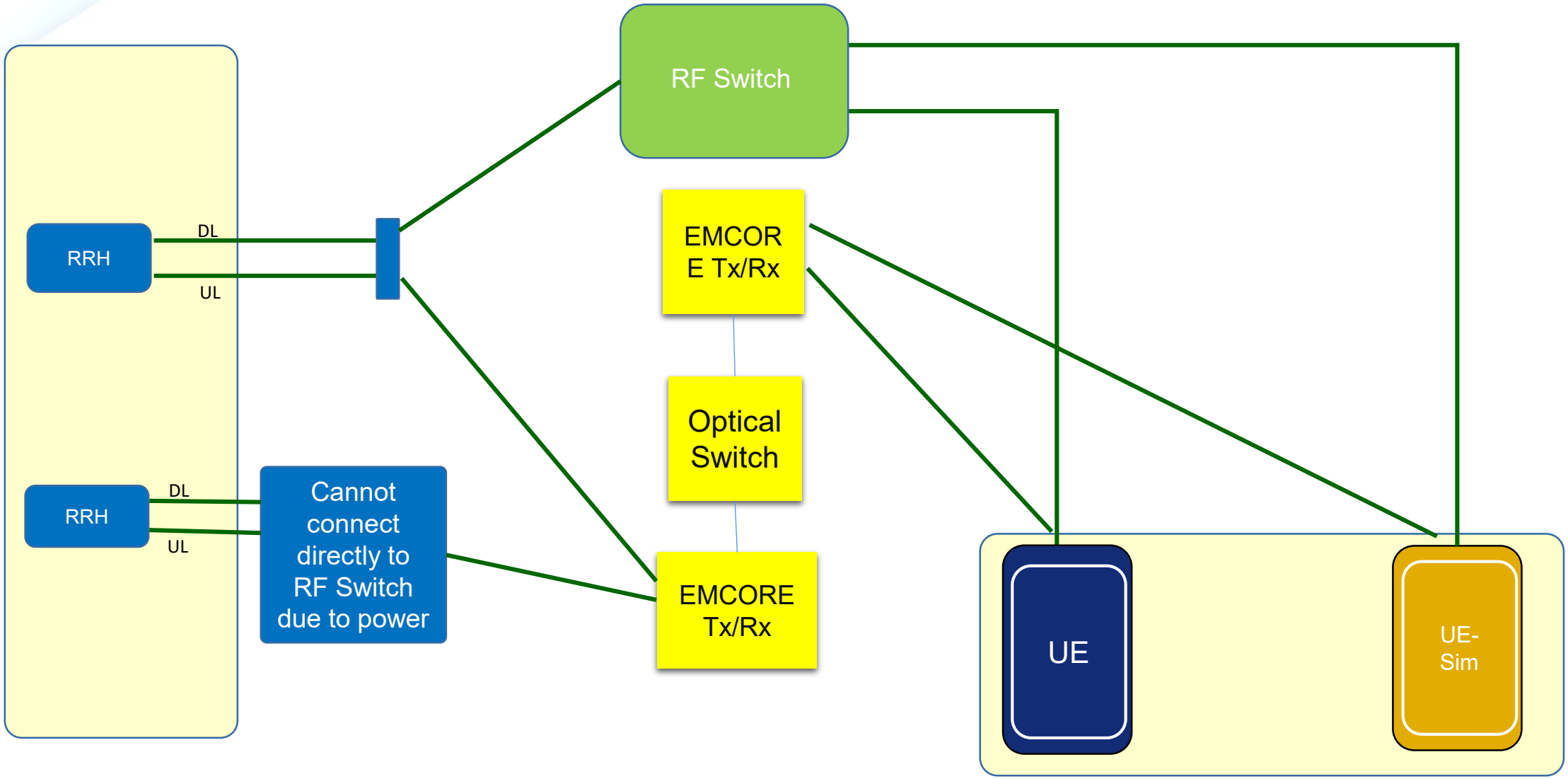
No latency; no synchronization and jitter; co-transmission; better cooperation; low power and weight at RRH

Analog Fiber Optics for 5G Base Station



- **Moving RF Front-End circuitry and/or beamforming circuits to the remote BBU.**

Analog Fiber Optics for 5G Test Lab



Analog Fiber Optics for 5G Test Lab

- **Switching in RF Domain vs. Optical Domain:**
  - Small number of ports on the RF switch (24 ports) → too many switches to build the network → too much insertion loss and too costly
  - Lower overall per-link cost (Tx + Rx + optical switch port pair) when compared to the RF switch port pair
  - Optical switch: 300 ports
- **Two Frequency Bands**
  - 20 MHz – 6500 MHz
  - 24 GHz – 40 GHz
- **Variable RF gains**
- **ACLR > 45 dBc**

Questions?

If you have any questions, please feel free to contact me at: Patrick_Chen@emcore.com