

**Scope:** Standardized Radio Access technologies across generations (2G, 3G, 4G, 5G)

**Responsibilities:** Defines protocol stacks (PHY, MAC, RLC, PDCP, RRC, NAS, SDAP), interfaces (N2, N3, E1, F1), UE categories, QoS, signaling, and base station behavior (gNB/eNB) with the core network.

3GPP  
(3rd Generation  
Partnership Project)

O-RAN  
Alliance

- **Scope:** Specifies open, disaggregated RAN architectures and interfaces for multi-vendor interoperability.
- Responsibilities:**
- Defines functional splits (O-CU-CP, O-CU-UP, O-DU, O-RU).
  - Specifies E2, A1, and open fronthaul interfaces.
  - Defines Near-RT RIC and control loops.

**Scope:** Focuses on software-defined RAN controllers and orchestration.

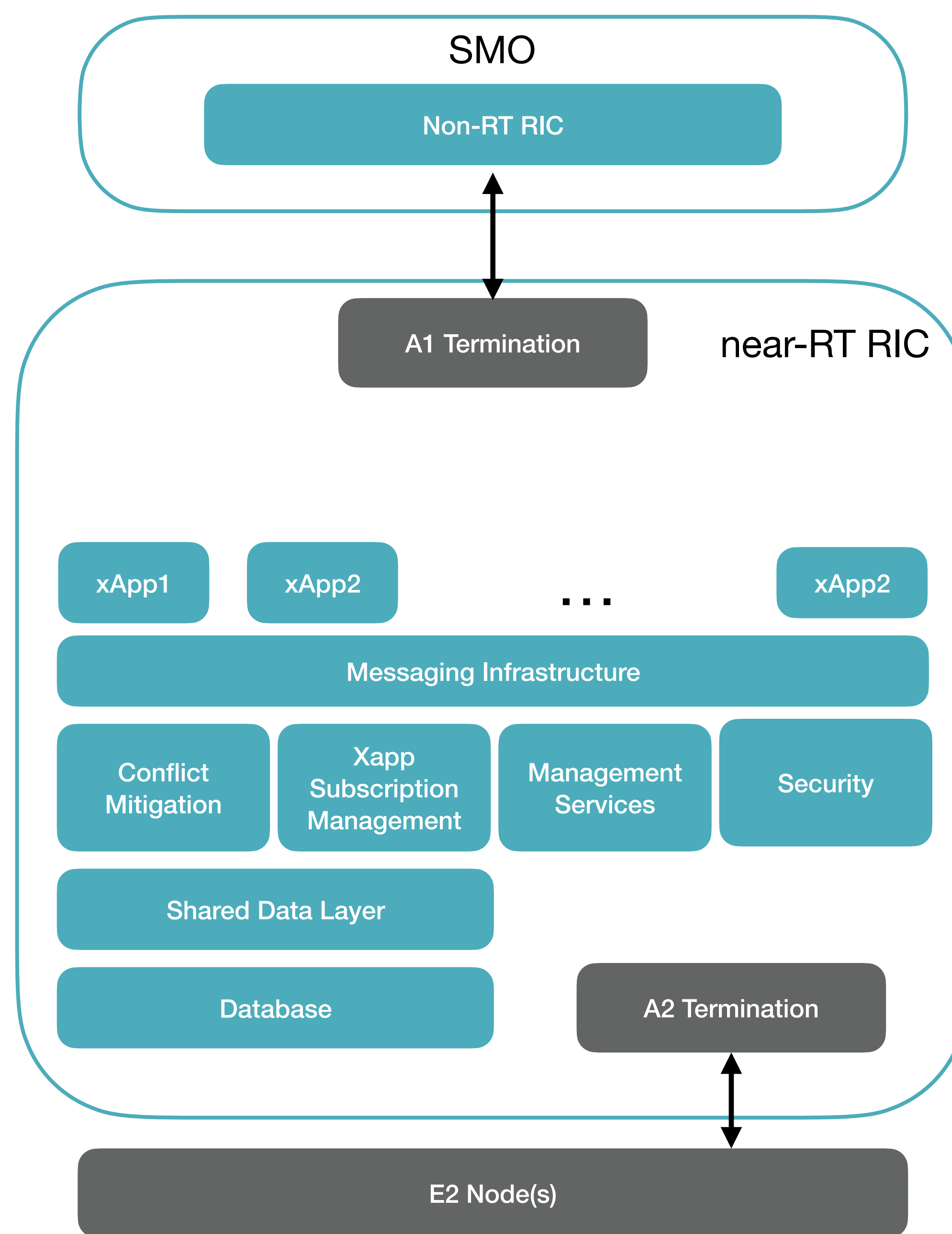
**Responsibilities:**

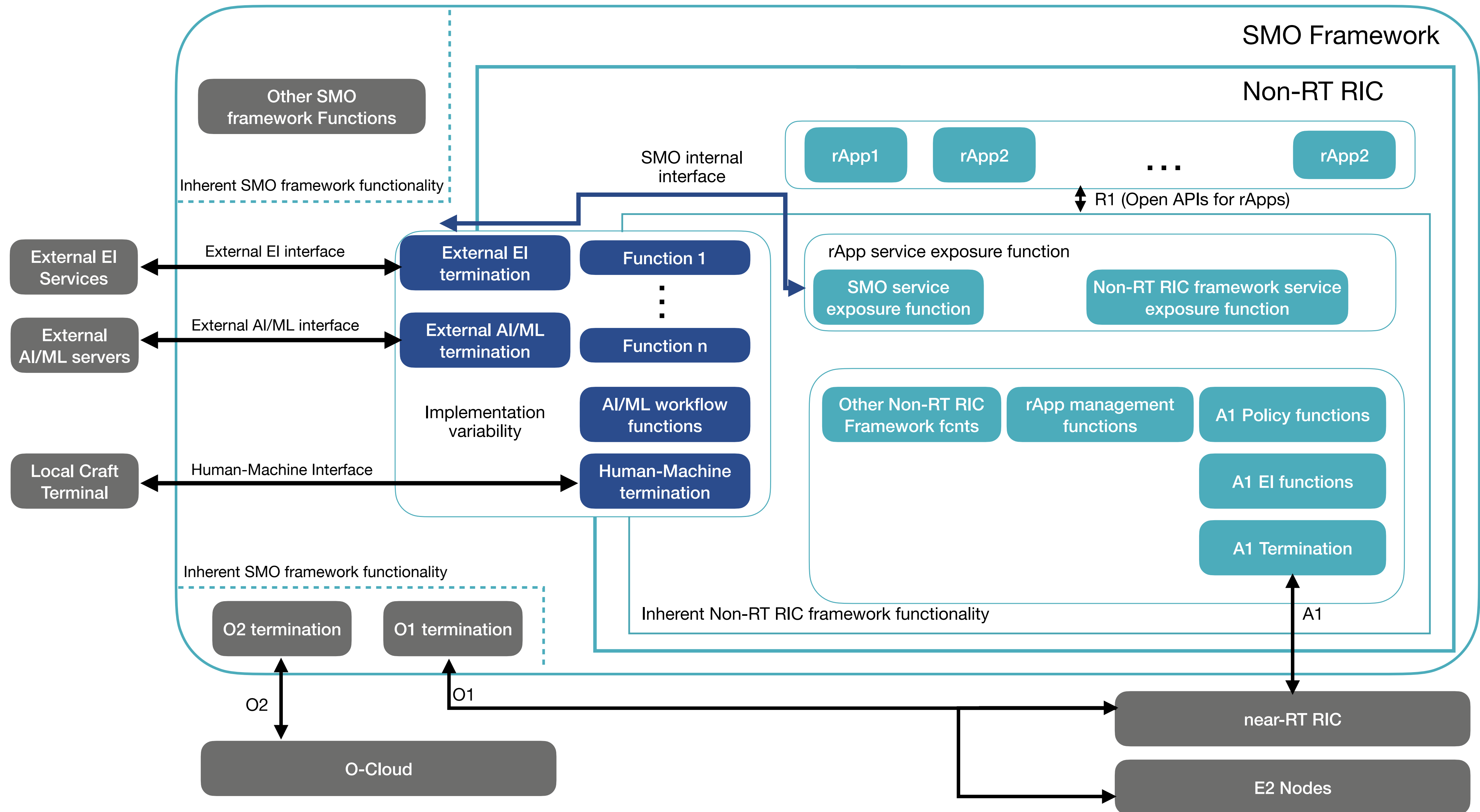
- Provides software platforms to control and manage disaggregated RAN elements.
- Implements policy-driven automation, network slicing, and optimization.
- Interfaces with O-RAN components via standard interfaces.

ONF SD-RAN

Telecom Infra

- Scope:** Physical deployment of RAN components and networking infrastructure.
- Responsibilities:**
- Supply radio units (O-RU), antennas, fiber fronthaul/backhaul, and data centers.
  - Ensure site installation, power, cooling, and maintenance.
  - integrate O-RAN and 3GPP components into a working network.





1.



Conventional Base Station  
Combined RF + BB

2.



RRH

CPRI



BBU

Mobile Front-haul Network  
Separated RRH and BBU

3.

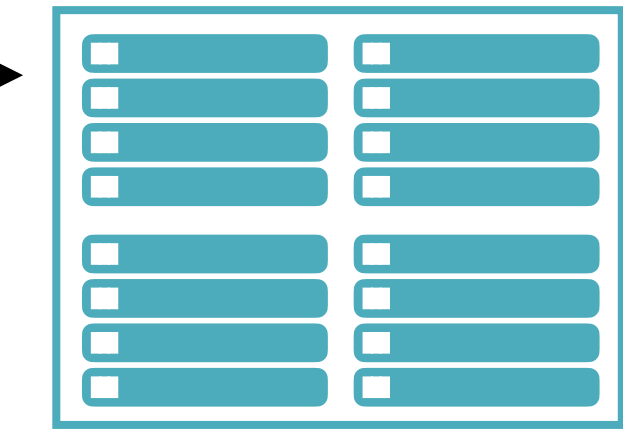


RRH

CPRI



RRH



BBU Pool

Centralized RAN  
Multiple BBUS Combined to Pools (often virtualized)

4.



Remote Radio Head

Fronthaul



Far Edge Data Center

Midhaul

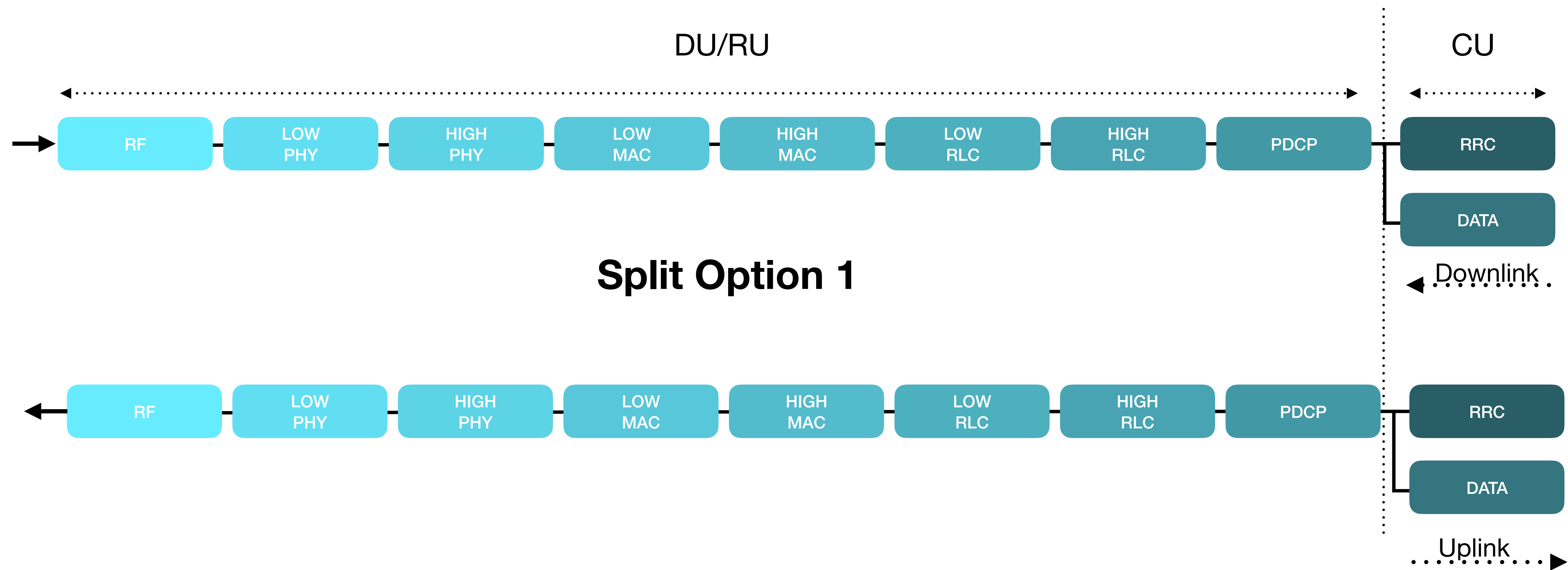


Edge Data Center

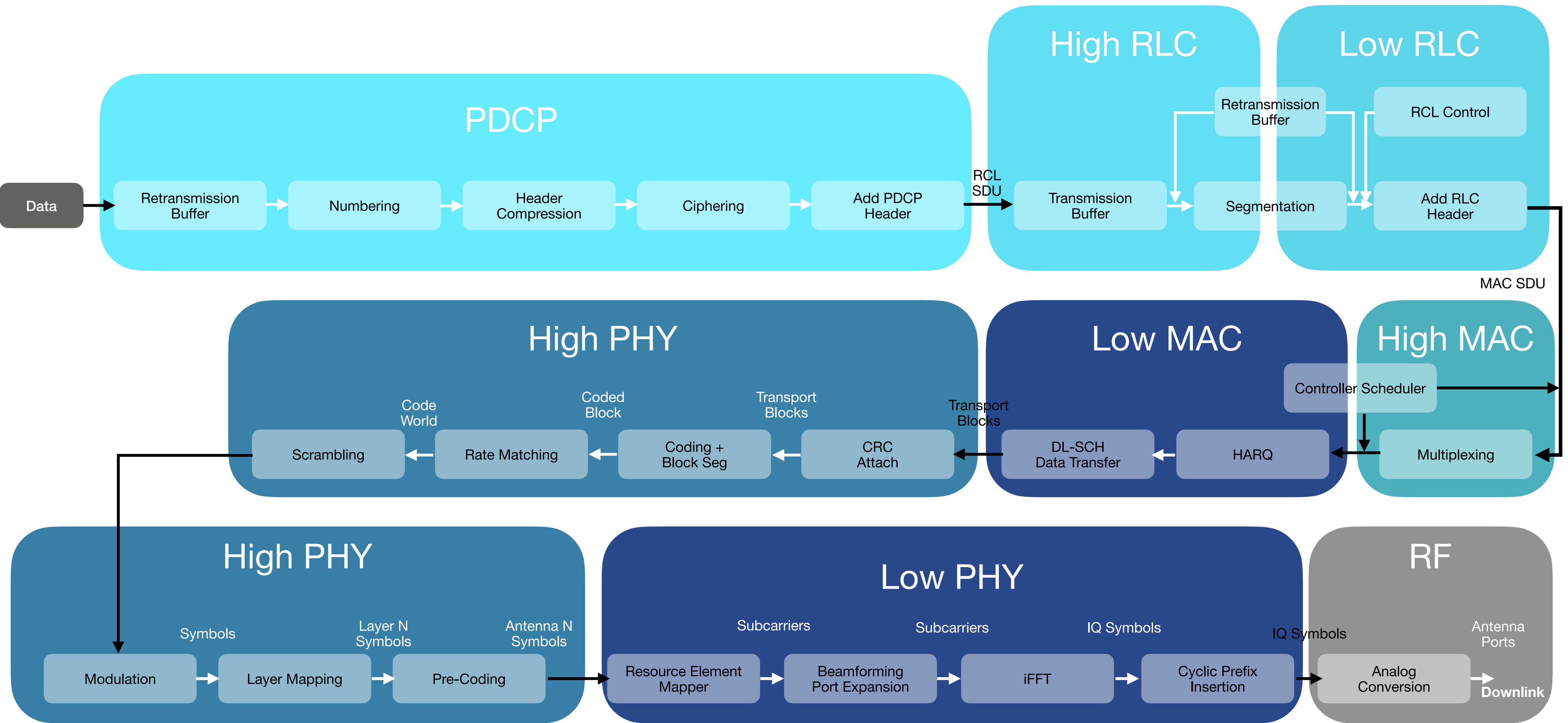
Backhaul



Mobile Core

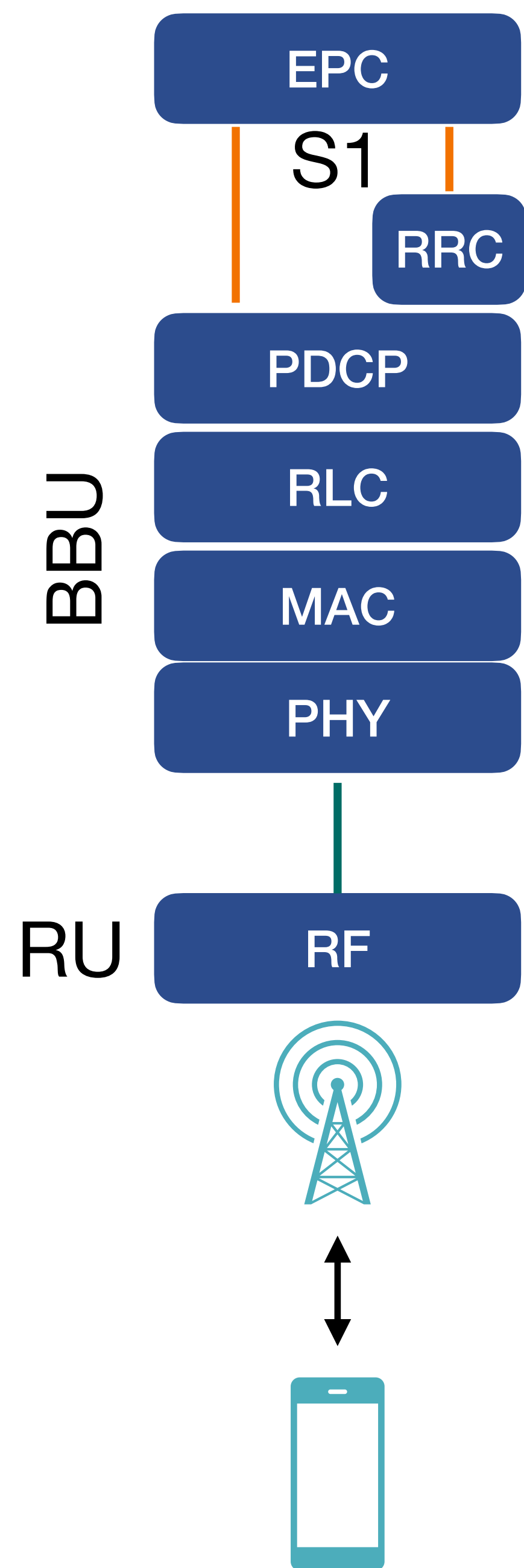




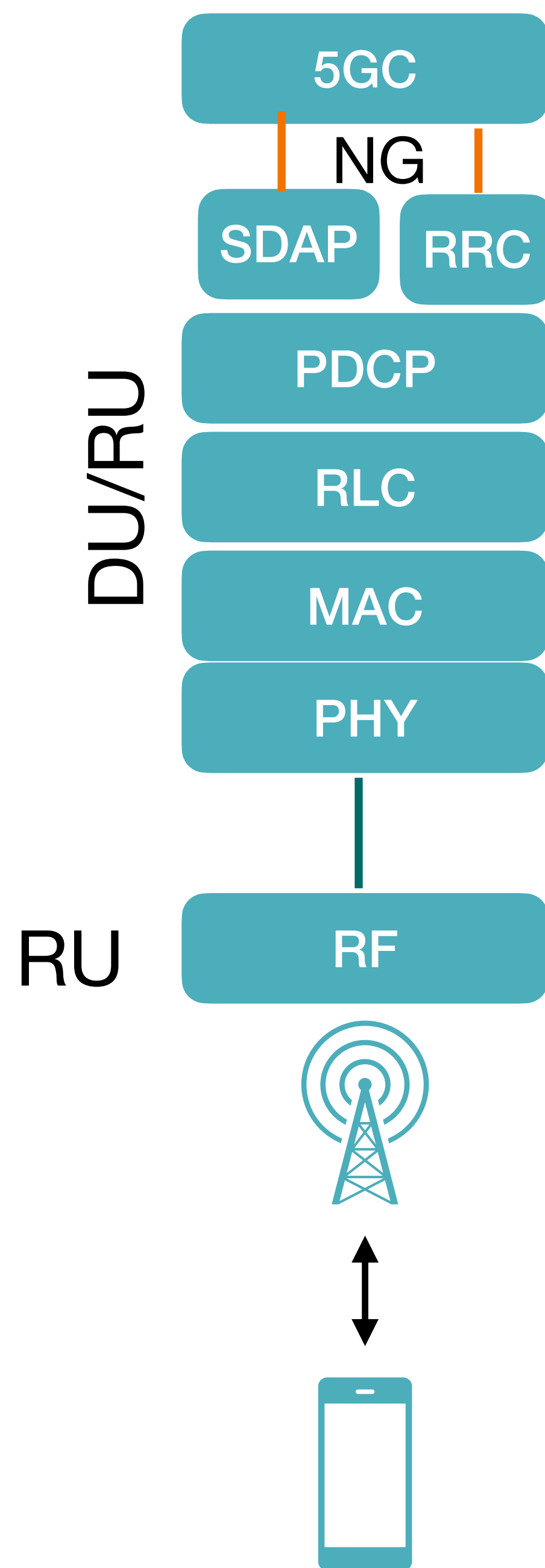




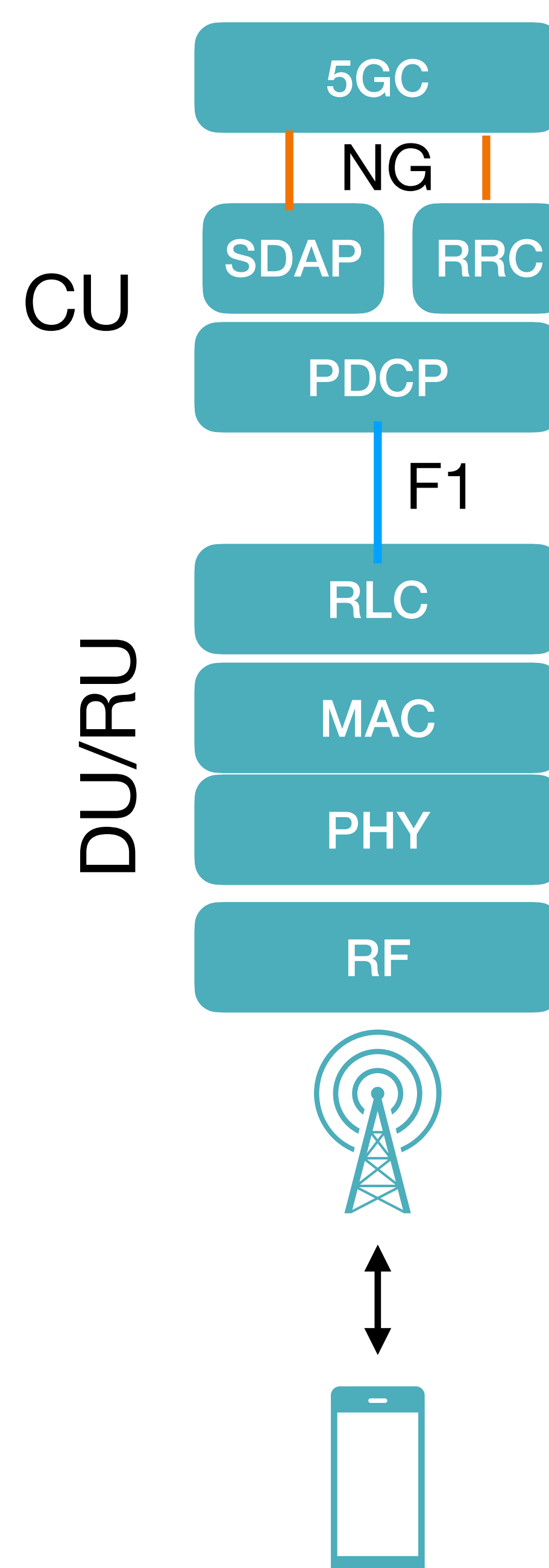
4G/LTE - Split 8



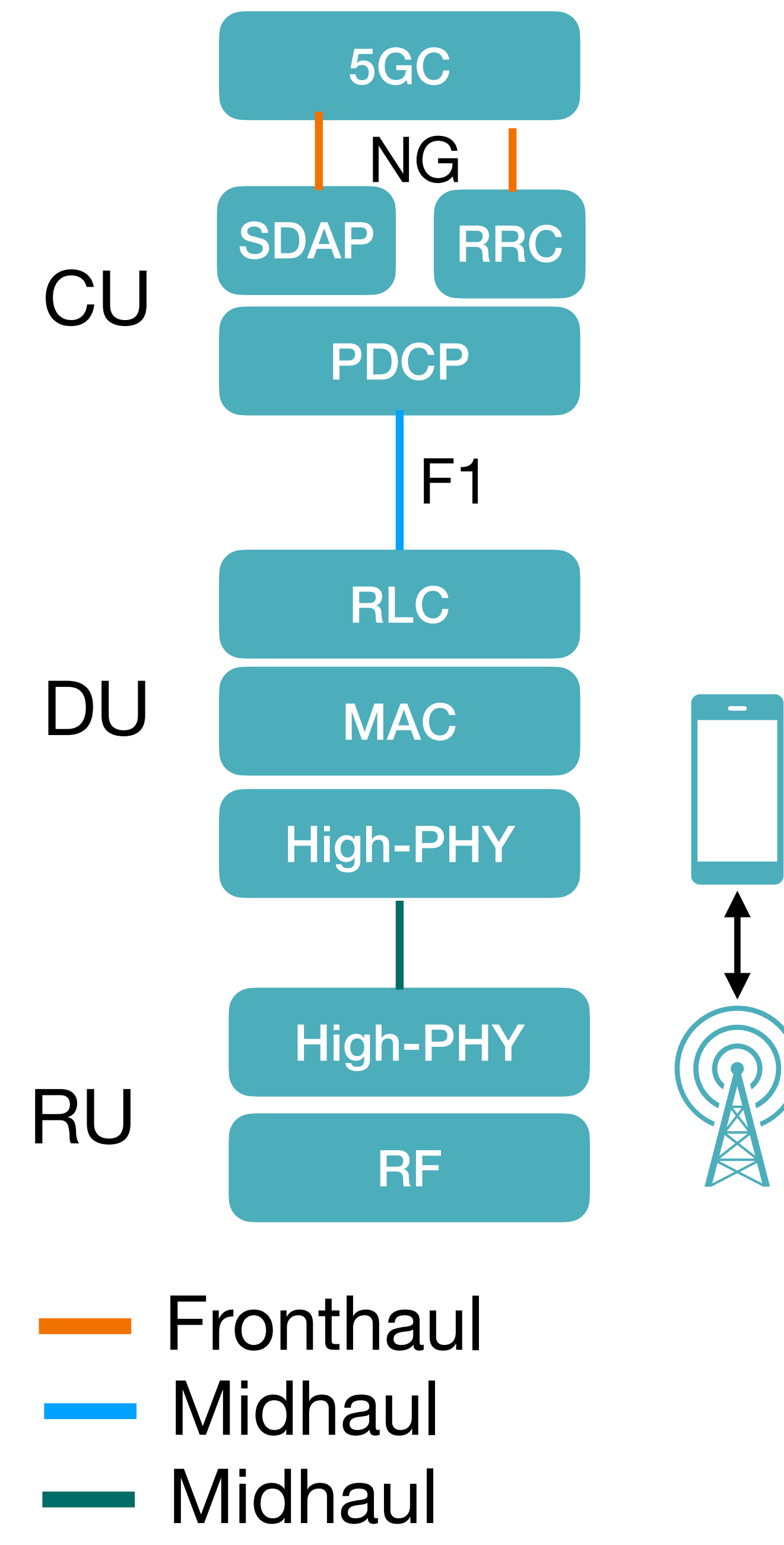
5G/NR - Split 8



5G/NR - Split 2

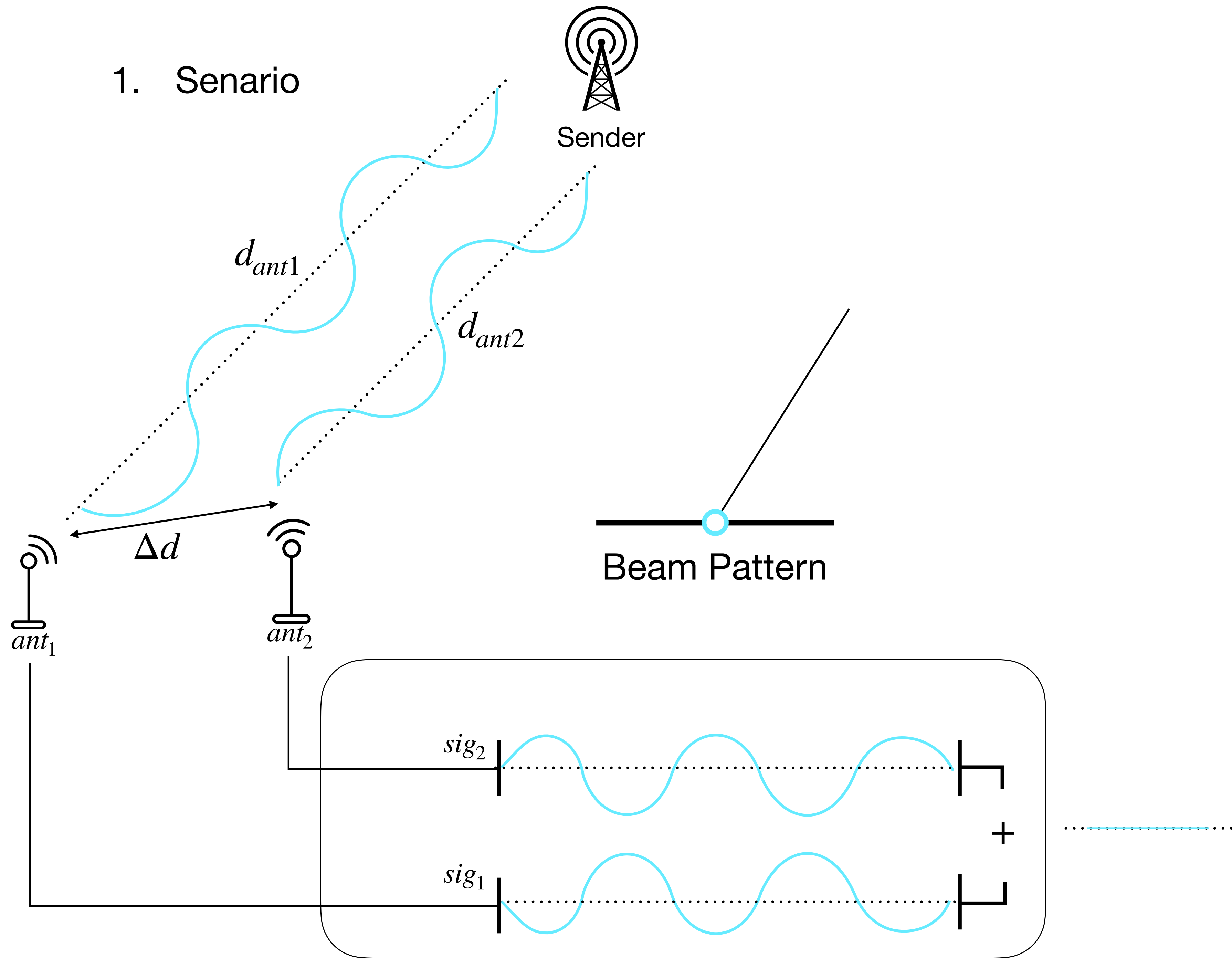


5G/NR - Split 7.x & Split 2

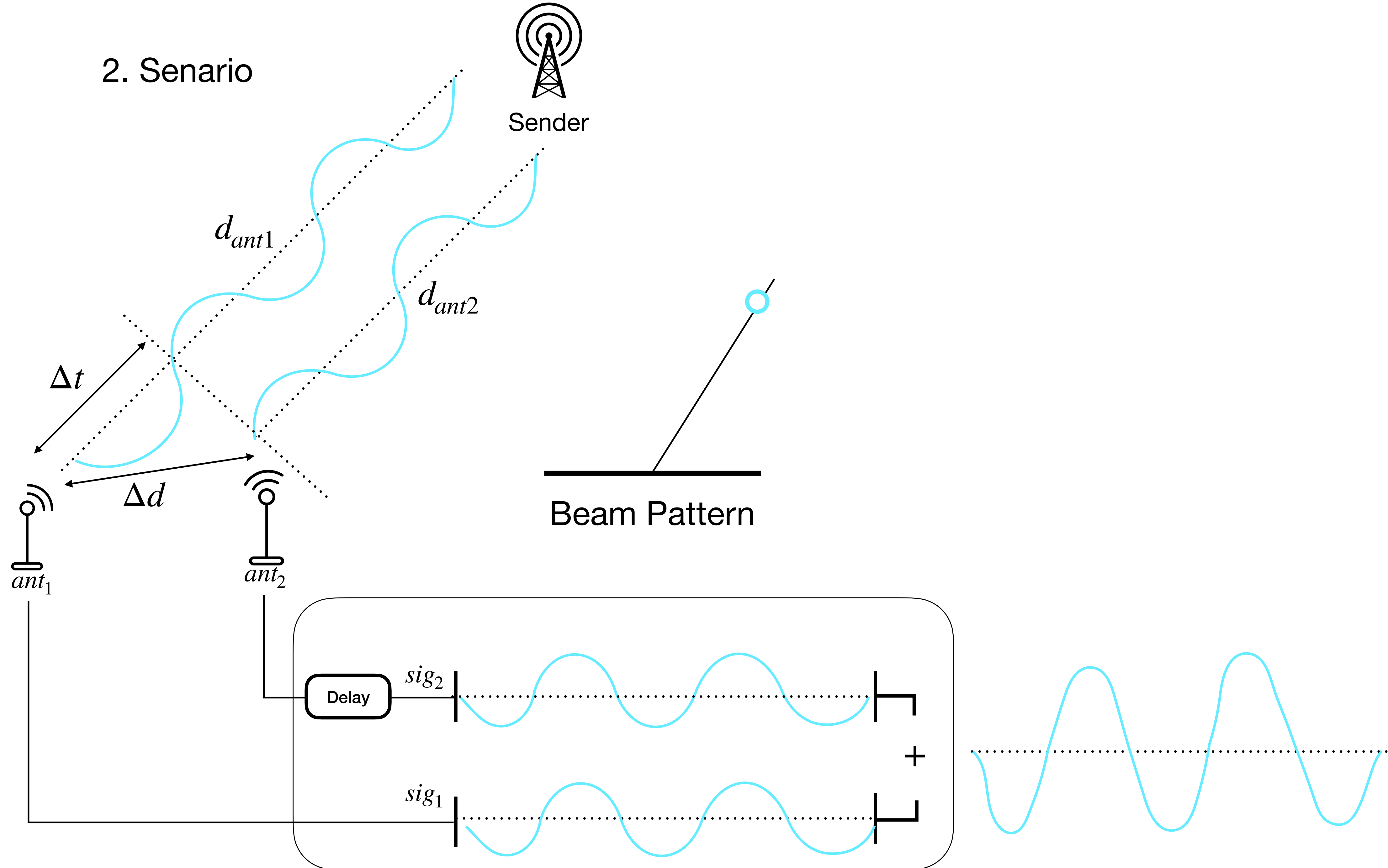


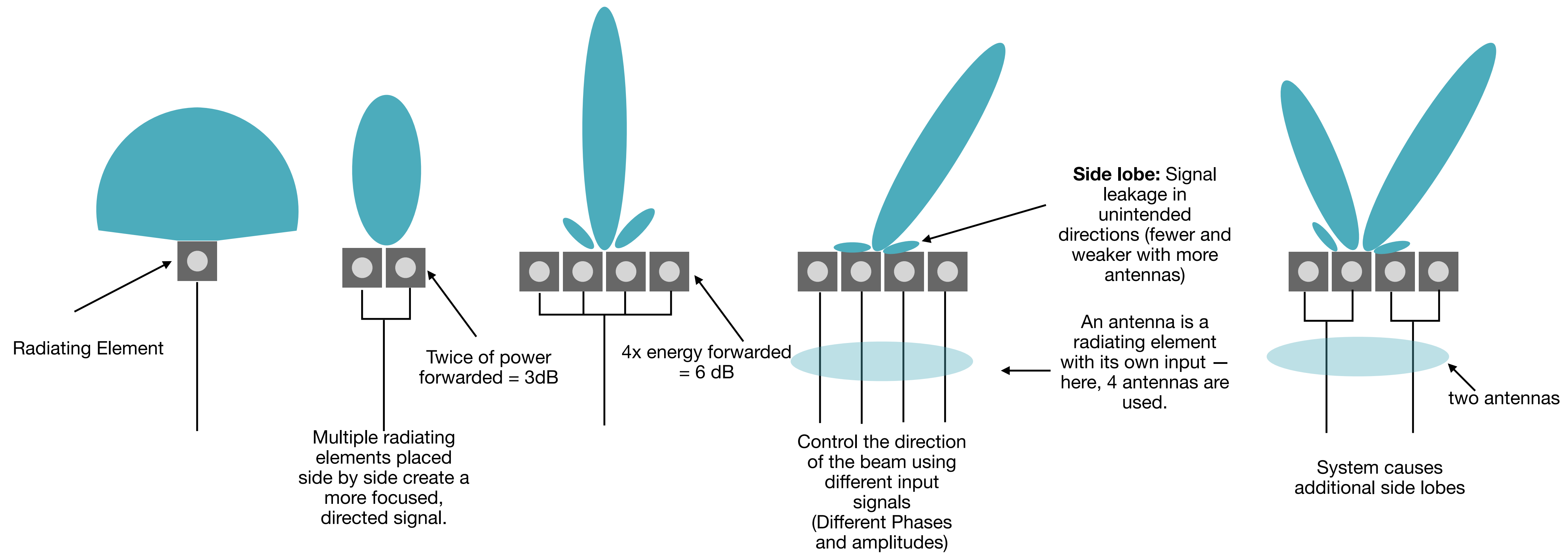
- Fronthaul
- Midhaul
- Midhaul

# 1. Senario

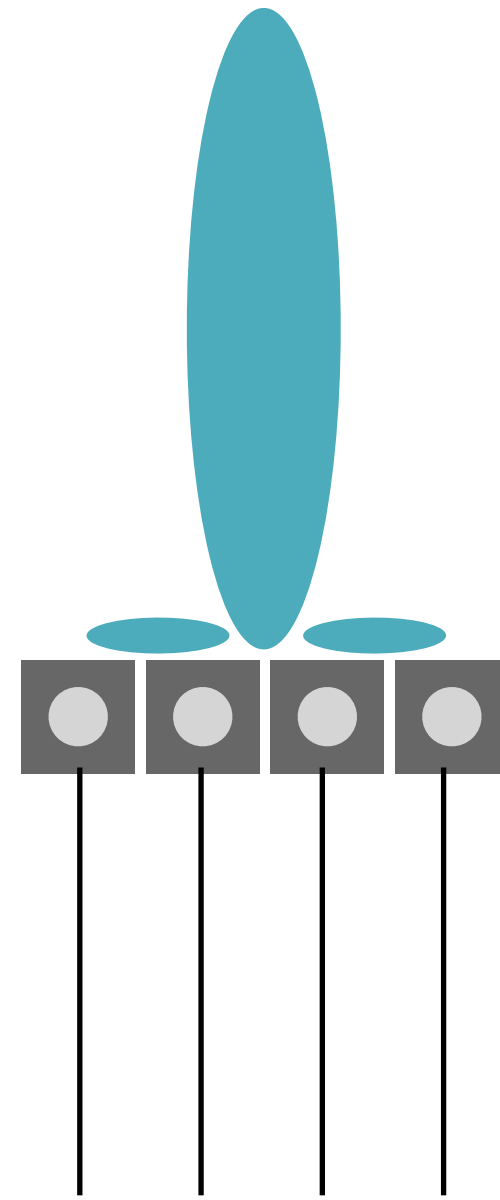


## 2. Senario

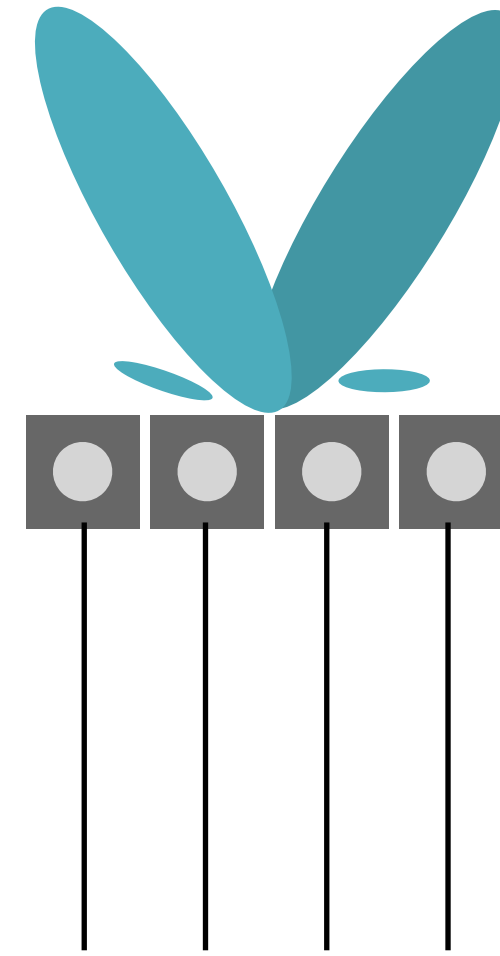




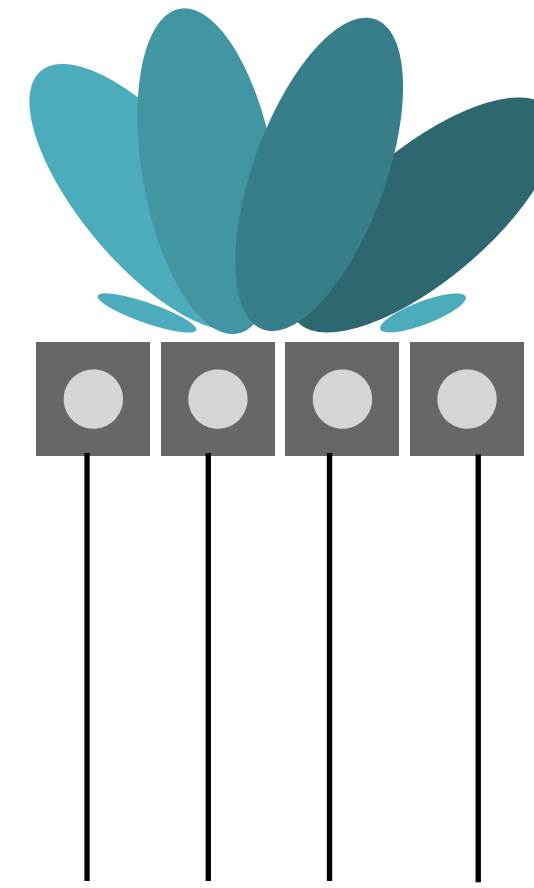
(a)



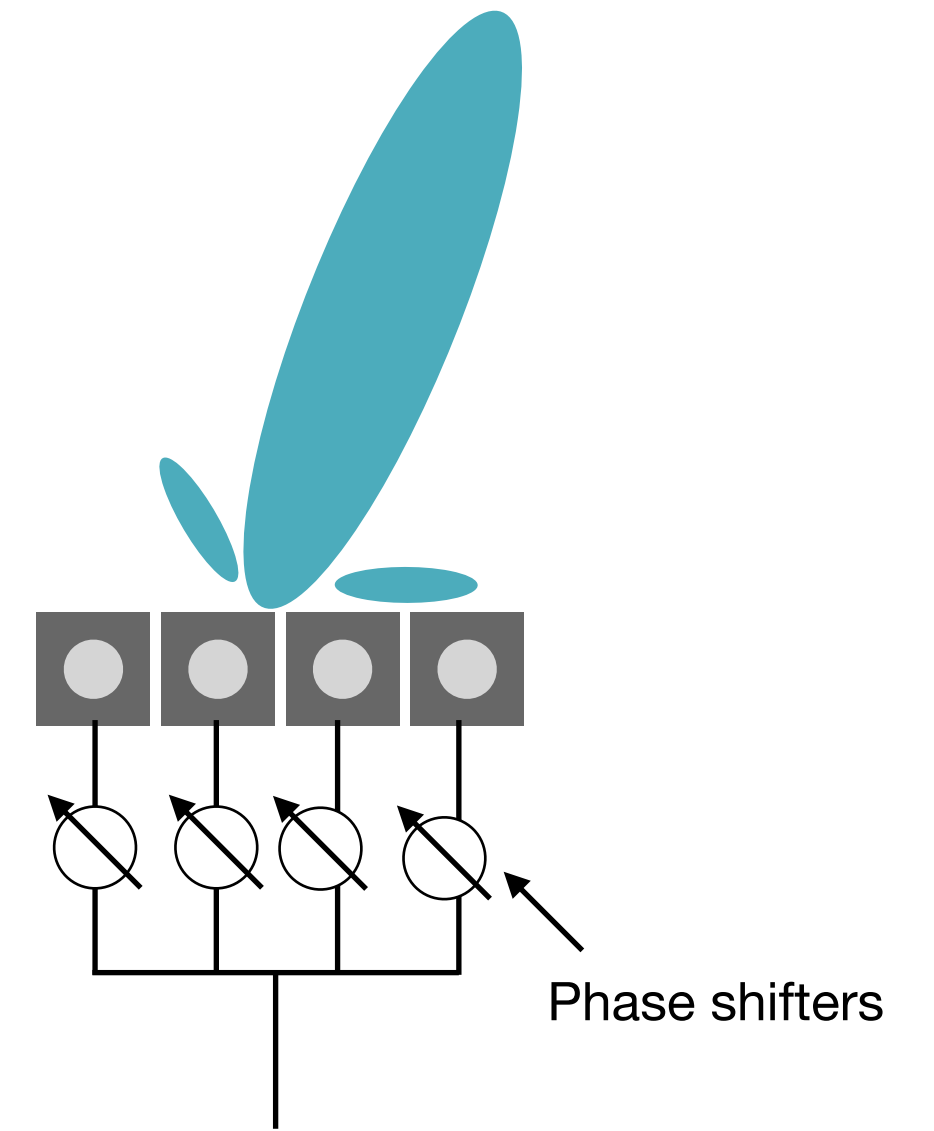
(b)



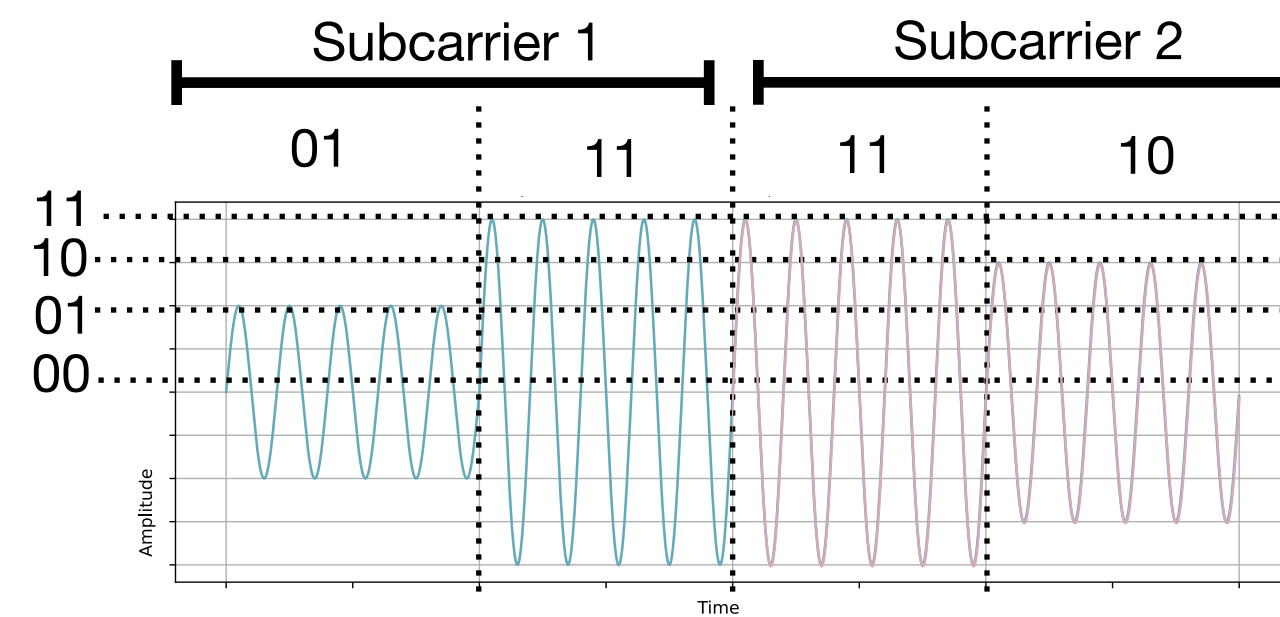
(c)



(d)



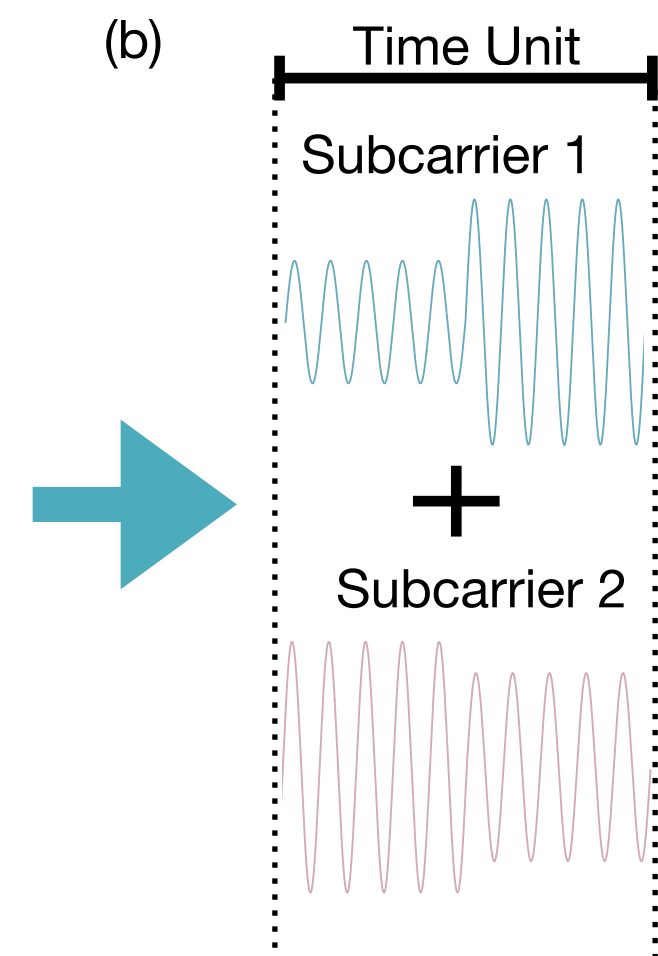
(a)



### Using multiple subcarriers

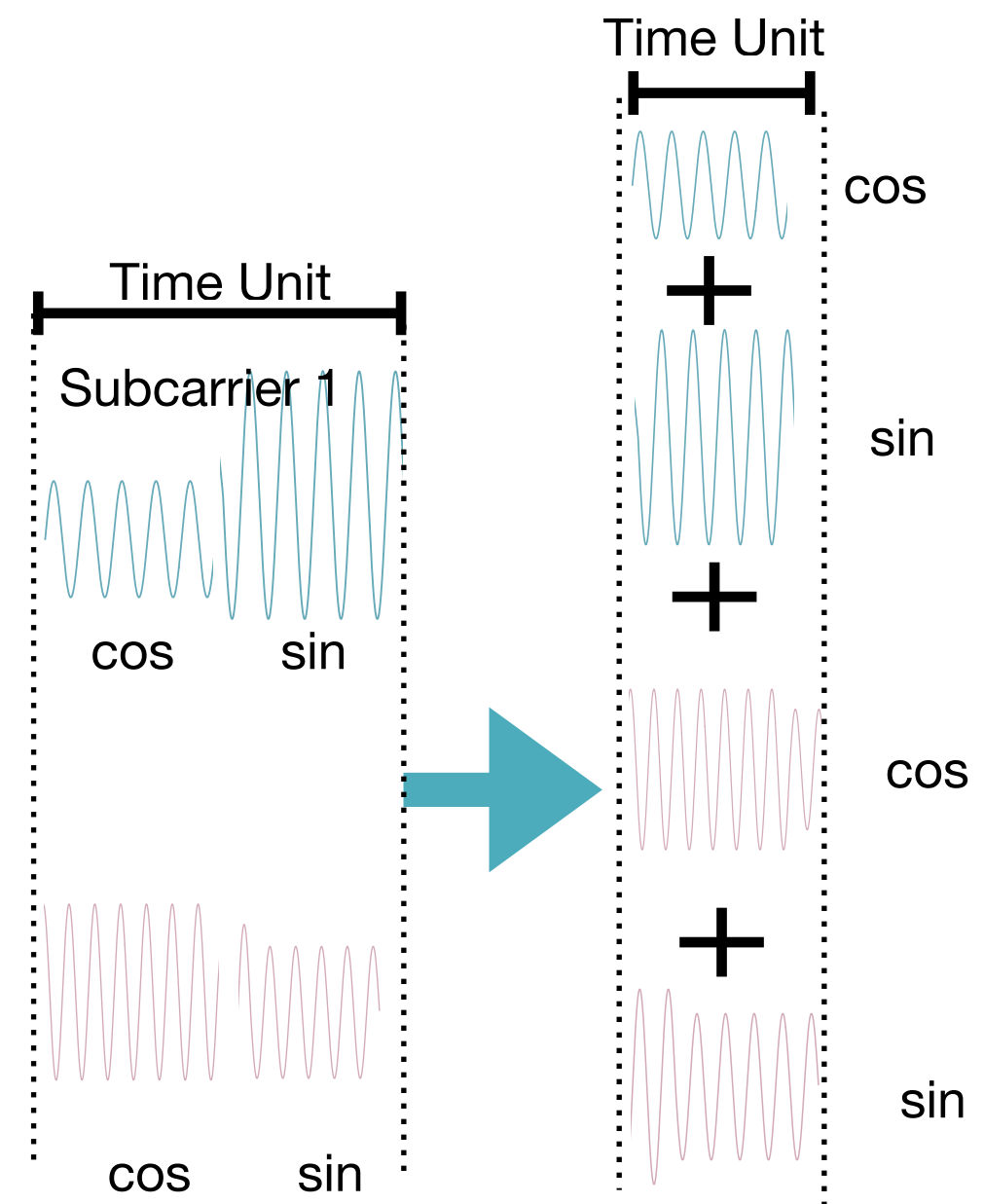
Spread data over multiple subcarrier waves

(b)

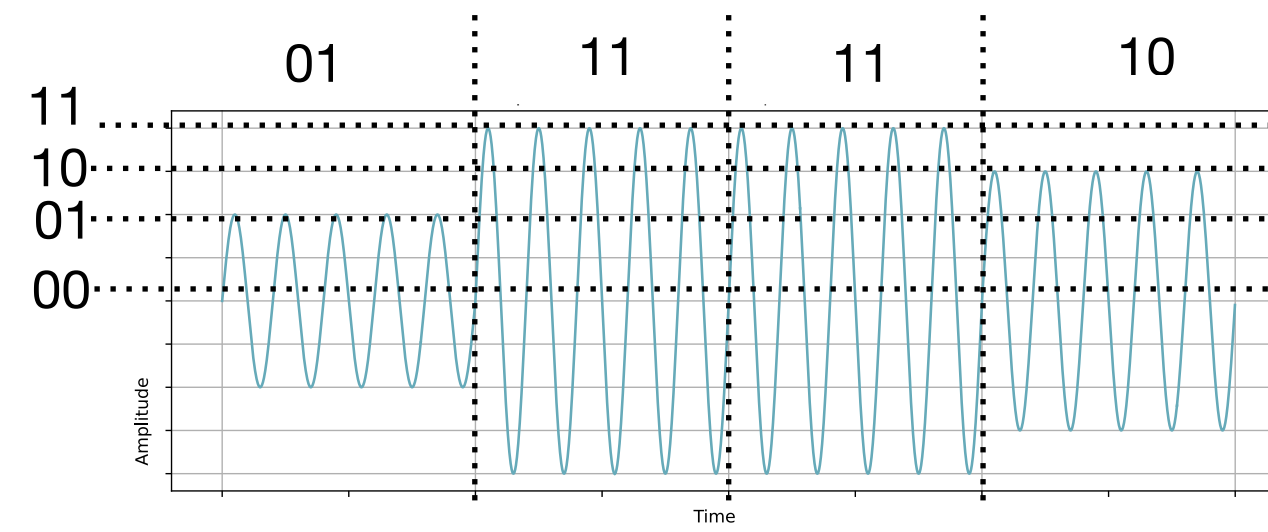


By combining these subcarriers double the information can be transmitted within a time unit

(c)



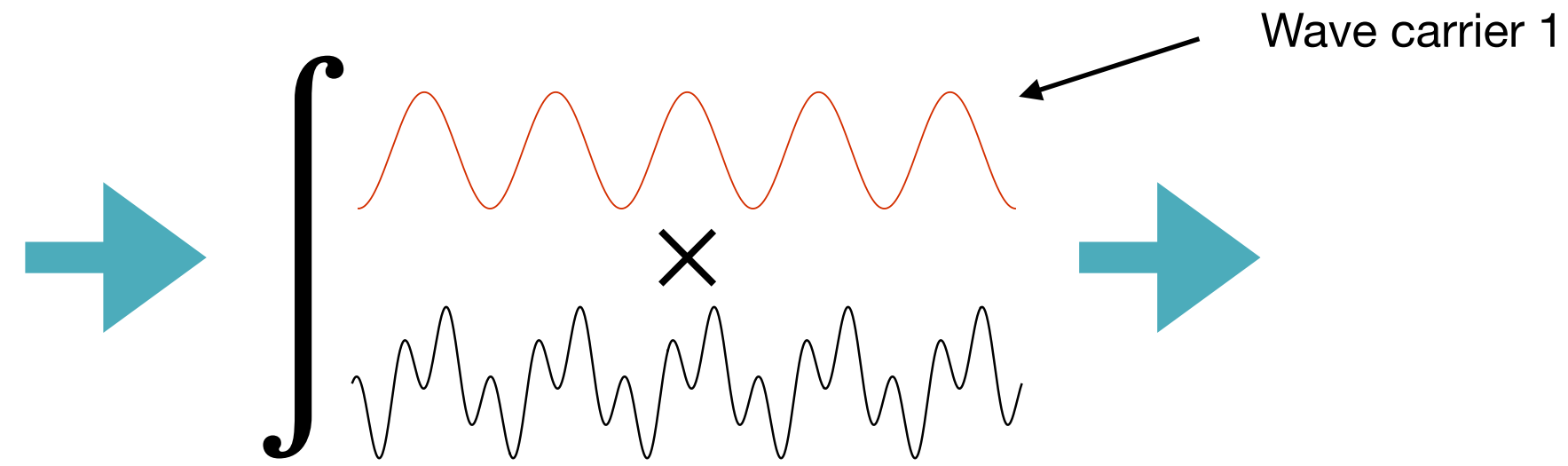
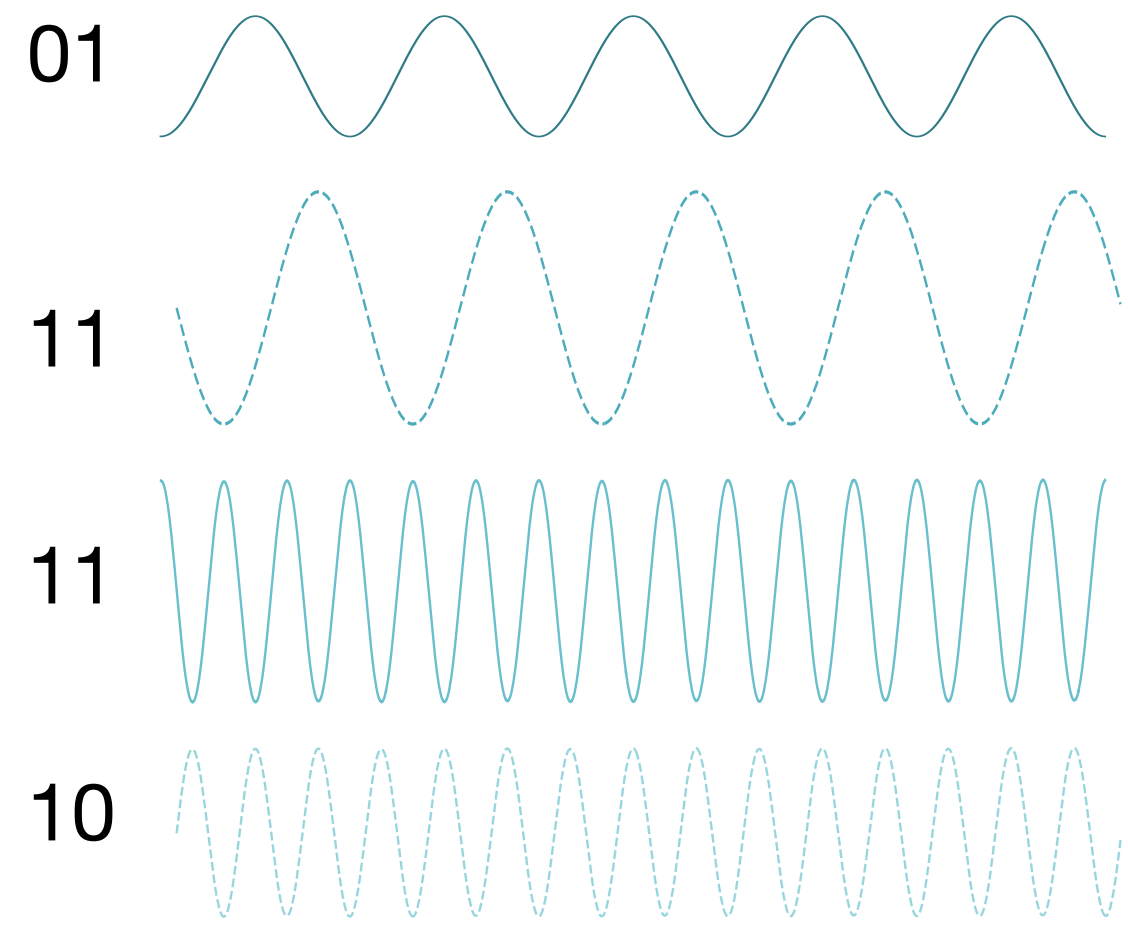
Each subcarrier uses a sinus signal and a cos signal allow to double the transmission per time unit. This technique is referred to as QAM modulation.



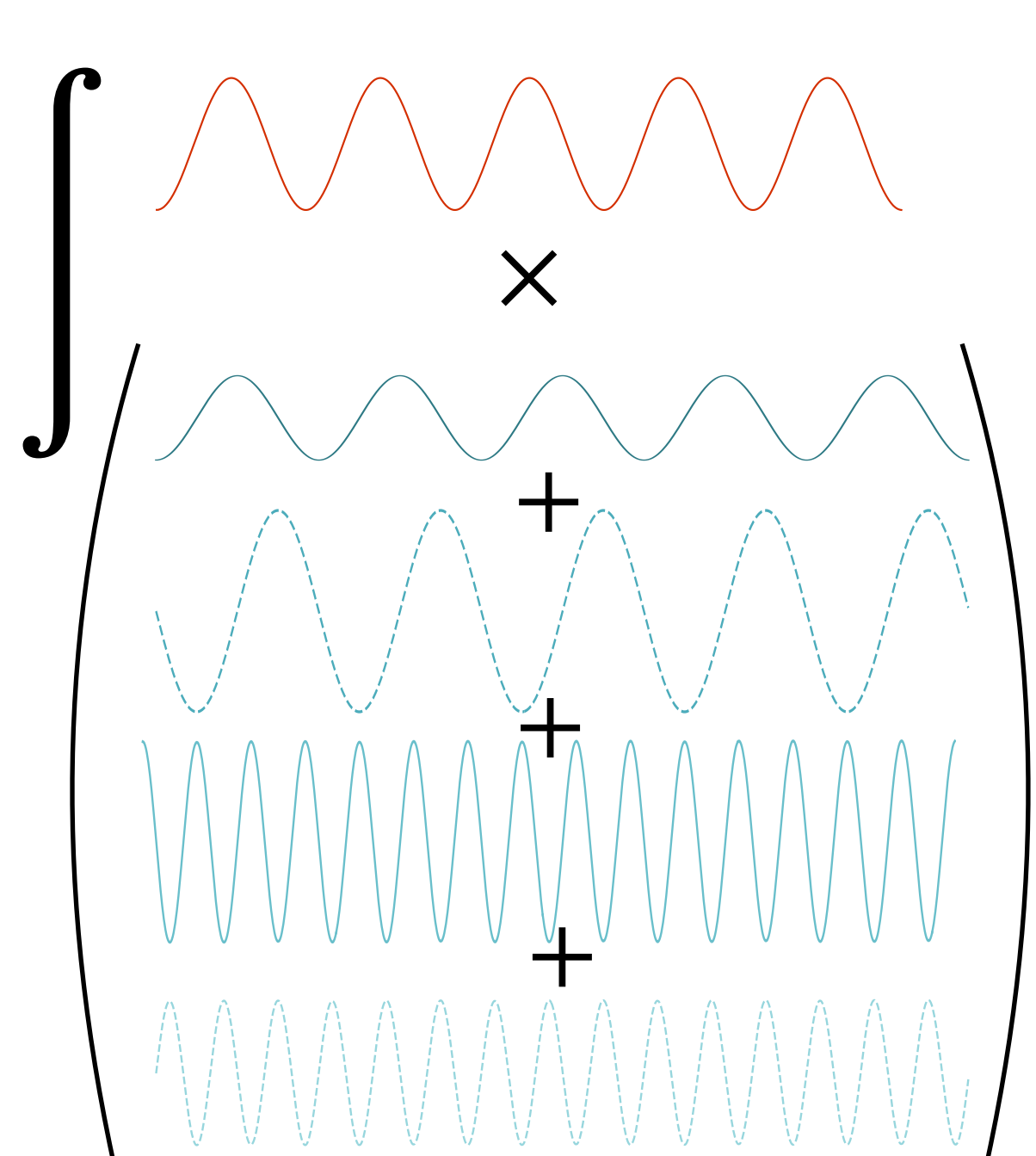
### Naive transmission approach

Using a single carrier wave and use the amplitude to transmit data.

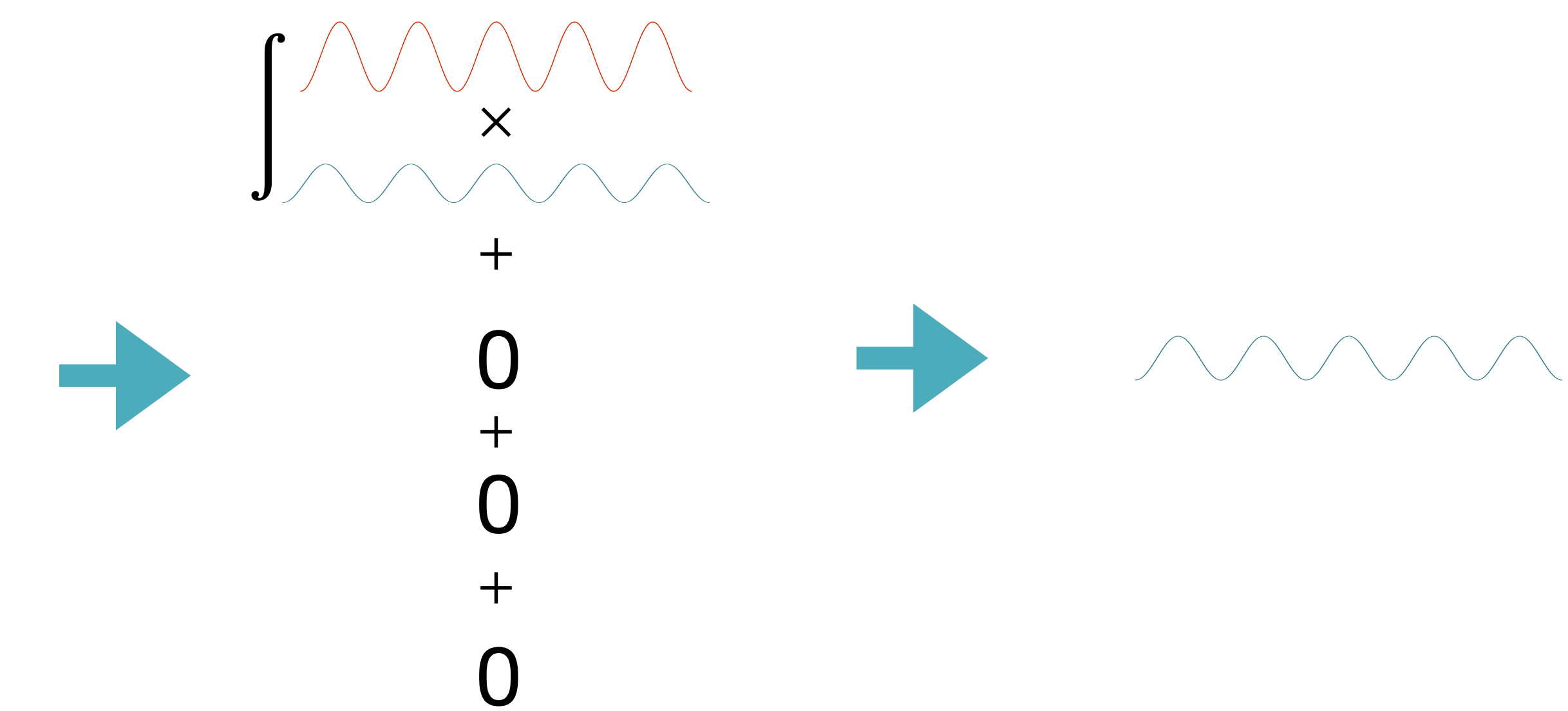
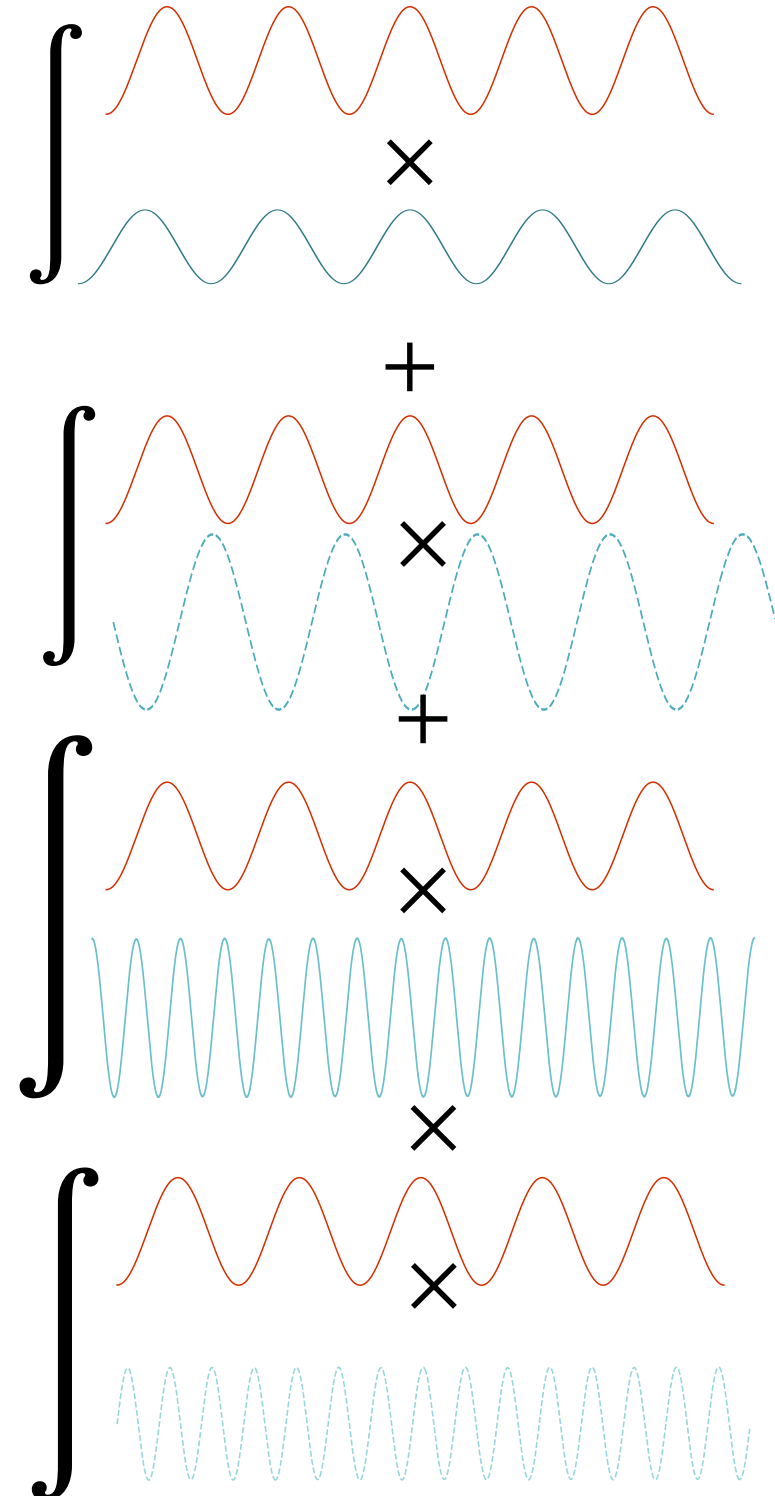




a) Extracting the amplitudes using a subcarrier from the received signal



b) Visualization with all the contributions of the other subcarriers



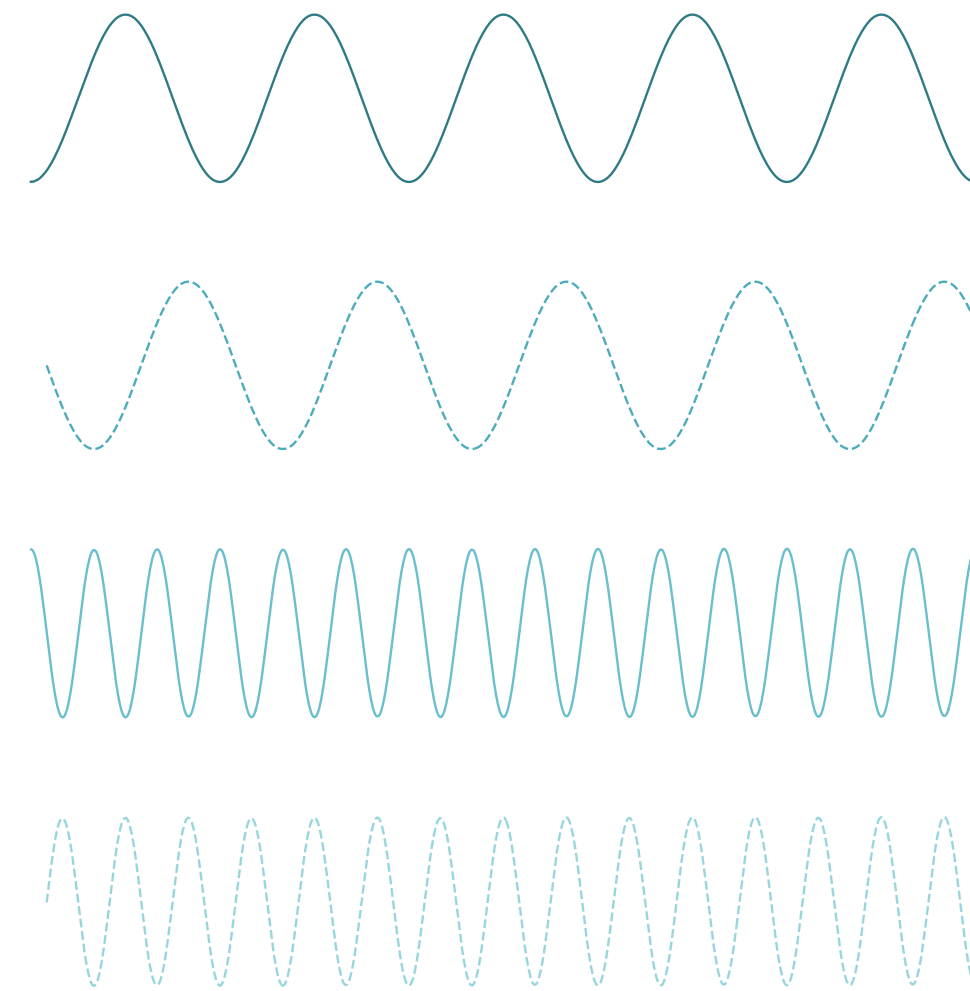
c) Contribution of other subcarriers vanish to zero resulting in the amplitude of the subcarrier from the received signal.



$$\cos(2\pi ft)$$

$f$  = subcarrier frequency

$t$  = time in seconds



(a) Take amplitudes of cos and sin wave and represent them as complex numbers

