# *Index Modulation Techniques for 5G Wireless Networks*

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- ITU 5G Research Group is composed of 10 professors from:
  - ITU Department of Electronics and Telecommunications Engineering (Wireless Communication Research Laboratory http://www.thal.itu.edu.tr/en/)
  - ITU Faculty of Computer and Informatics Engineering (http://www.bb.itu.edu.tr/en)
  - ITU Informatics Institute (http://www.be.itu.edu.tr/index.php/en)

- We focus on the following design issues towards 5G wireless networks:
  - ✓ Physical Layer (PHY) /MAC Layer Design
  - ✓ RF Electronics and Antenna Design
  - ✓ Network Layer Design

- In this presentation, we focus on spectral and energy-efficient PHY solutions towards 5G wireless networks.

# *Index Modulation Techniques for 5G Wireless Networks*

- The wireless community is still working day and night to come up with new and more effective PHY solutions towards 5G networks.

- There has been a growing interest on *index modulation (IM)* techniques over the past few years.

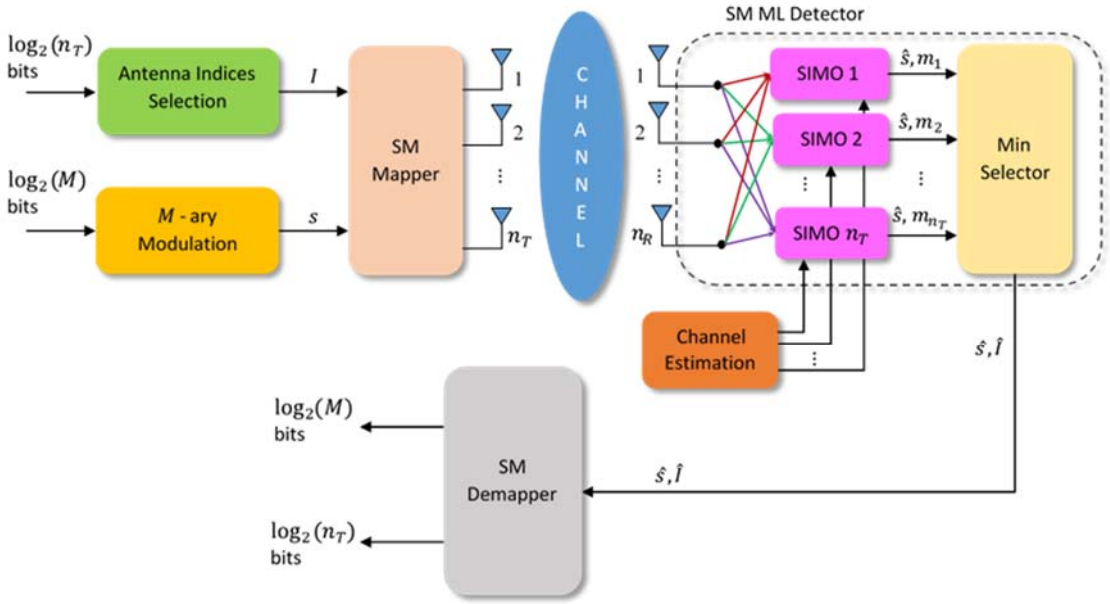
- Spatial modulation (SM) and orthogonal frequency division multiplexing with IM (OFDM-IM) schemes appear as two interesting as well as promising applications of the IM concept.

- SM techniques have attracted significant attention over the past few years with numerous published papers.

- Although having strong and well-established competitors such as V-BLAST and STC systems, SM schemes have been regarded as possible candidates for spectral and energy-efficient next generation MIMO systems.

- It has been shown that the OFDM-IM scheme can provide attractive advantages over classical OFDM, which is an integral part of many current wireless standards.

# *Spatial Modulation for 5G*




There are two information carrying units in SM:
1) indices of transmit antennas
2) M-ary constellation symbols.

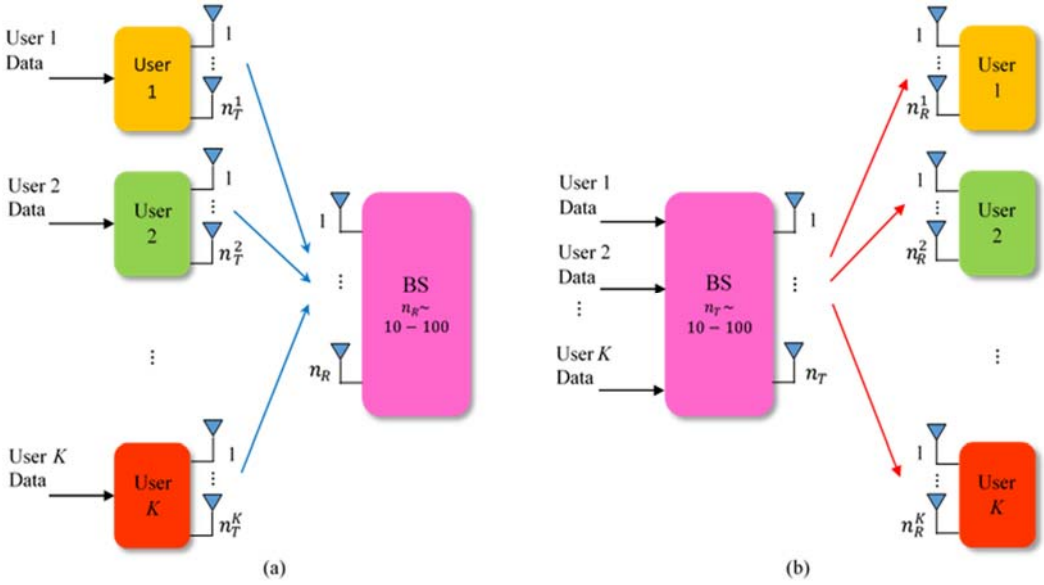
Spectral Efficiency [bpcu]

$$\log_2 n_T + \log_2 M$$

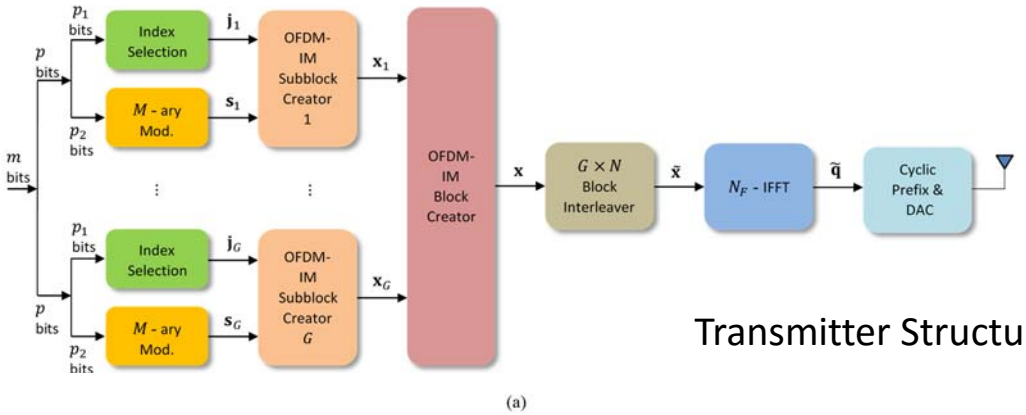
Massive MU-MIMO systems with SM

(a) An uplink transmission scenario where User $k$ has $n_T^k$ transmit antennas available for SM and the BS has $n_R \sim 10 - 100$ receive antennas

(b) A downlink transmission scenario where User $k$ has $n_R^k$ receive antennas and the BS has $n_T \sim 10 - 100$ transmit antennas available for SM.

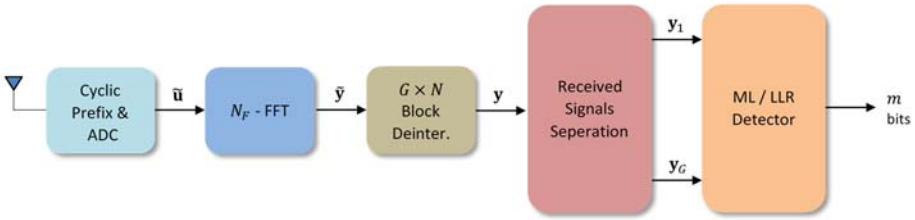


# *OFDM with Index Modulation for 5G*




(a)

Transmitter Structure




(b)

Receiver Structure


| | *bits* | *indices* | |
|---|---|---|---|
| $N = 4, K = 2,$ $\binom{4}{2} = 6$ $\Rightarrow p_1 = 2$ bits | {00}, {01}, {10}, {11} | $[1\ 3]^T, [2\ 4]^T, [1\ 4]^T, [2\ 3]^T$ | Reference Look-up Table |
| $N = 32, K = 16,$ $\binom{32}{16} = 601,080,390$ $\Rightarrow p_1 = 29$ bits | {0 1 0 0 0 0 1 1 0 1 0 0 0 1 1 0 0 0 1 1 1 0 1 1 0 0 0 1 0} | [29 28 27 26 25 19 17 16 15 14 13 12 11 8 4 2]$^T$ | Combinatorial Number Theory |

(c)

Index Selection Examples

- In the OFDM-IM scheme, the incoming bit stream is split into index selection and *M*-ary constellation bits.
- According to the index selection bits, only a subset of available subcarriers are selected as active, while the remaining inactive subcarriers are not used and set to zero.
- On the other hand, the active subcarriers are modulated according to the *M*-ary constellation bits.