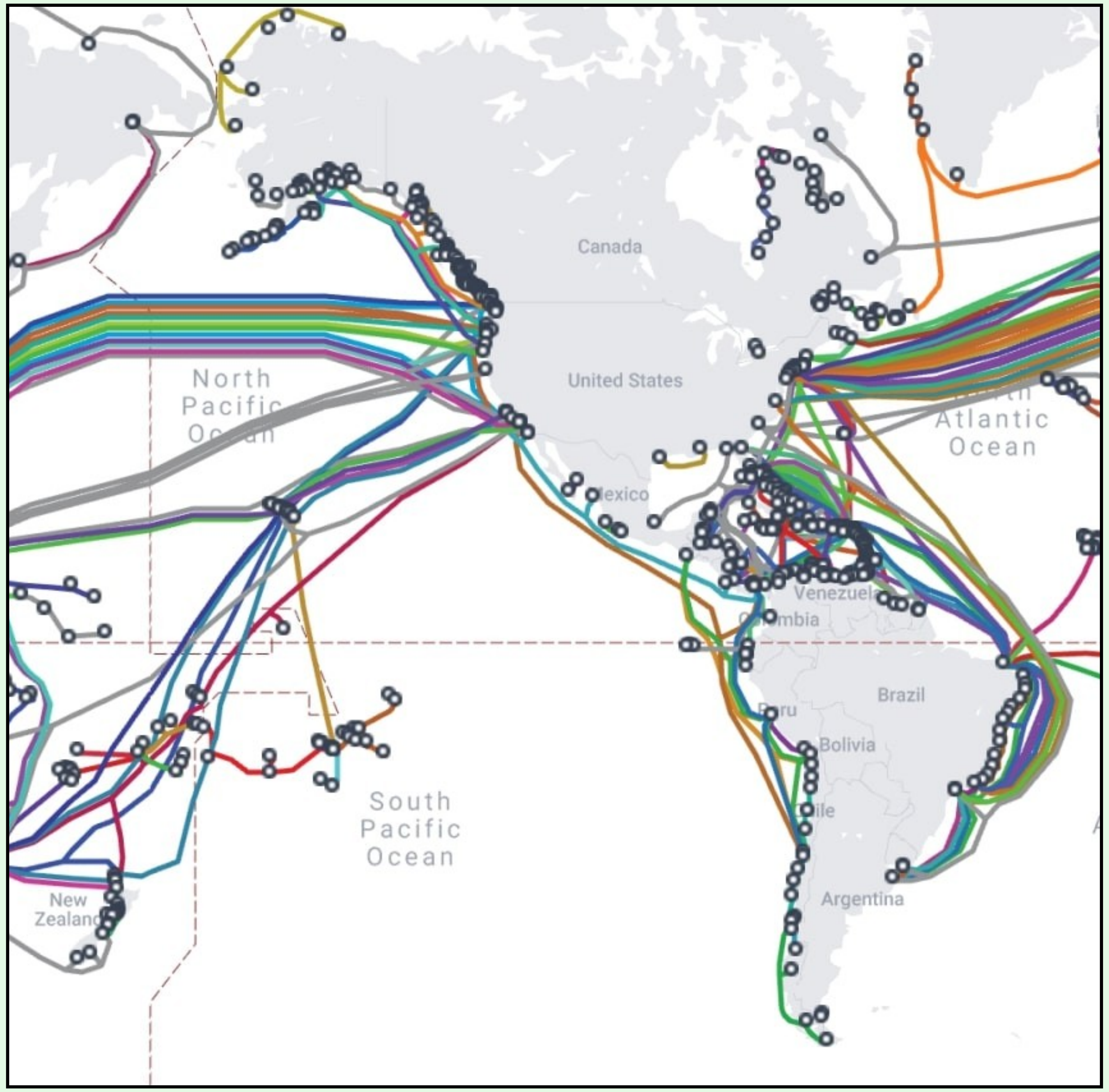
YOLANDA REYES

EECE 653 SOFTWARE DEFINED RADIO

FINAL PRESENTATION:

ADVANCED MODULATION FORMATS



California State University Chico

SMART
SCIENCE, MATHEMATICS AND RESEARCH FOR TRANSFORMATION
PART OF THE NATIONAL DEFENSE EDUCATION PROGRAM

LAND ACKNOWLEDGMENT

We acknowledge and are mindful that Chico State stands on lands that were originally occupied by the first people of this area, the Mechoopda, and we recognize their distinctive spiritual relationship with this land, the flora, the fauna, and the waters that run through campus.

We are humbled that our campus resides upon sacred lands that since time immemorial have sustained the Mechoopda people and continue to do so today.

MECHOOPDA INDIAN TRIBE OF CHICO RANCHERIA, CALIFORNIA

https://www.mechoopda-nsn.gov/

ROADMAP

- ***Types of Modulation***

  Analog: Single Sideband
  Impulsive: Pulse Amplitude
  Numerical: DQPSK
  Experimental: Orbital Angular Momentum

- ***References***

- ***Questions and Comments***

TYPES OF MODULATION

- **Analog**

    Continuous signal variation using amplitude, frequency or phase.

    Susceptible to noise and interference over long-distances.

- **Impulsive**

    Discrete signal variation also using amplitude, frequency or phase.

    Better performance in noisy environments, digital processing techniques to maintain data integrity.

TYPES OF MODULATION

- **Numerical**

  Special case of the impulsive modulation type, using discrete signals.

  Used to encode analog values, instead of binary sequences of data, for increased accuracy.

- **Experimental**

  Aims to increase data transmission capacity using quantum mechanics.

  Exploits properties of electromagnetic wave that are not utilized in traditional modulation techniques.

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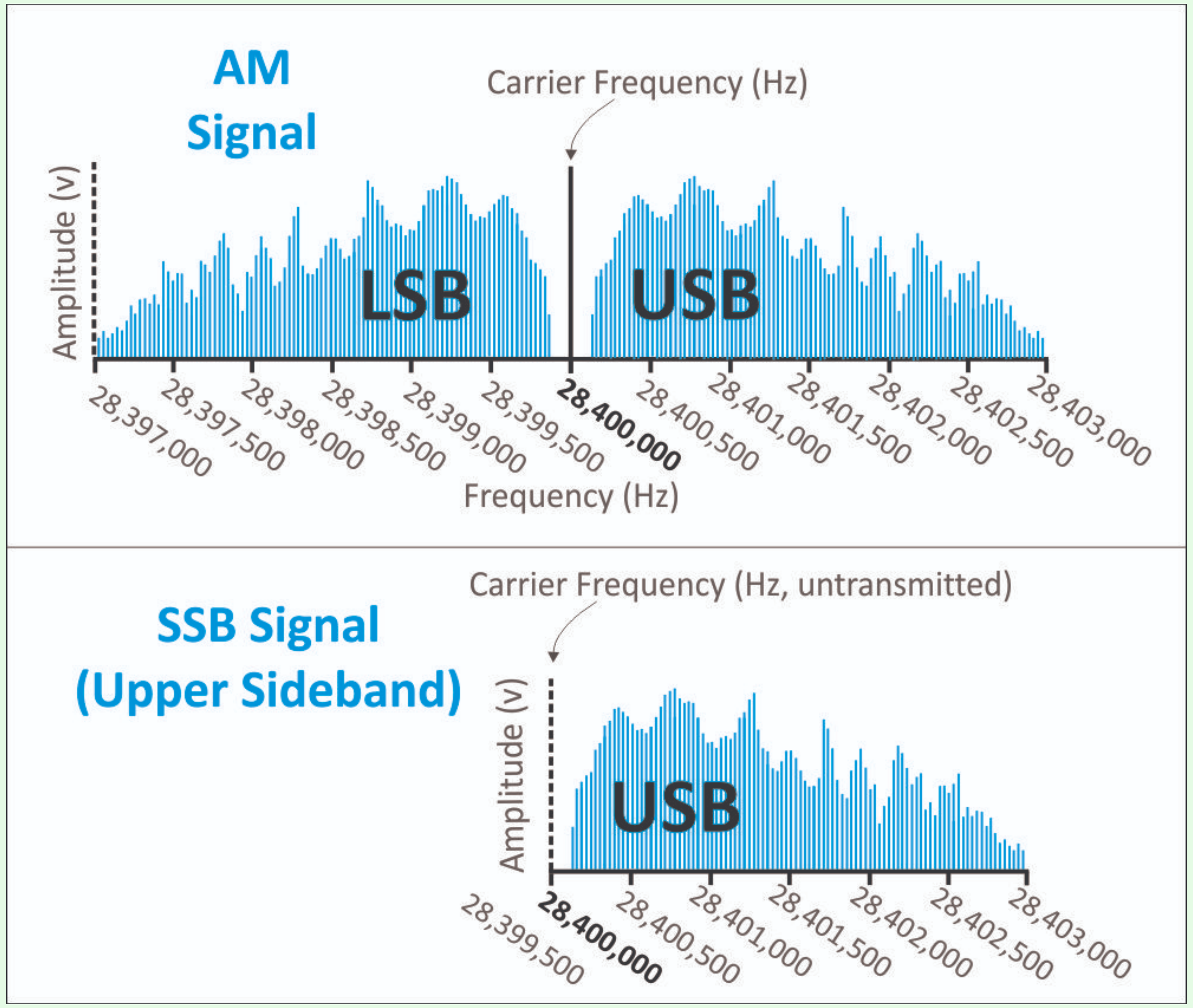
ANALOG: *SINGLE SIDEBAND*

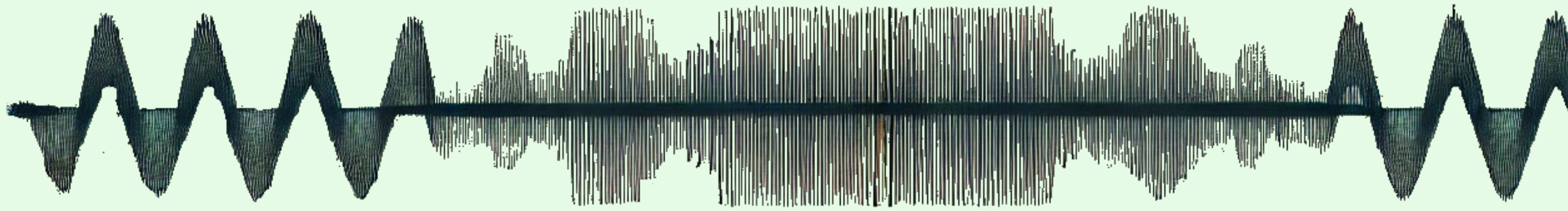


Increase in power efficiency since the carrier and one sideband are eliminated.

Increases the complexity of modulation and demodulation, Local Oscillator (LO) a must!

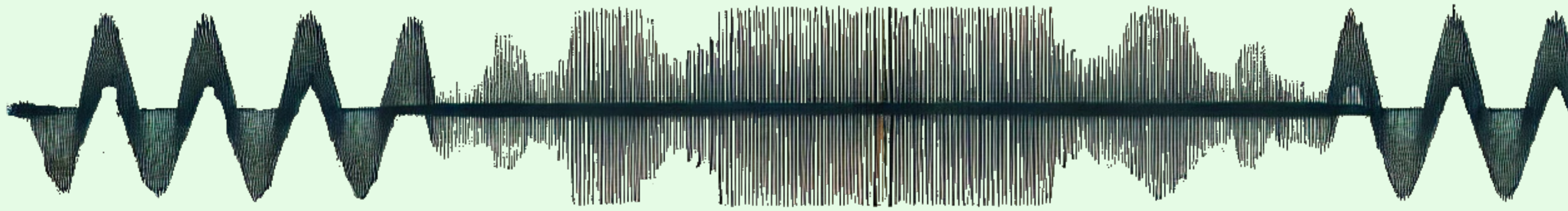
Suitable for long-range communication, a variation on Amplitude Modulation (AM).

ANALOG: *SINGLE SIDEBAND*



- **Advantages**
  - Special case of the digital modulation type, using discrete signals.
  - Crowded spectrum? Benefits from reduced bandwidth requirements.
  - Since the carrier signal and one sideband is removed overall power across the transmitted band is increased.
- **Disadvantages**
  - Requires efficient transmissions, across vast distances.
  - Condition of the ionosphere affects transmissions!

ANALOG: *SINGLE SIDEBAND*



- **Ham Radio**

  Narrower bandwidth allows more bands for broadcasting without interference from adjacent channels.

  Ionospheric changes can affect the signal at different frequencies, tuning is a must!

- **Over-the-Horizon Radar**

  Provides good signal-to-noise ratio compared to full carrier transmissions.

  The narrower bandwidth of transmissions decreases effects of ionospheric disturbances.

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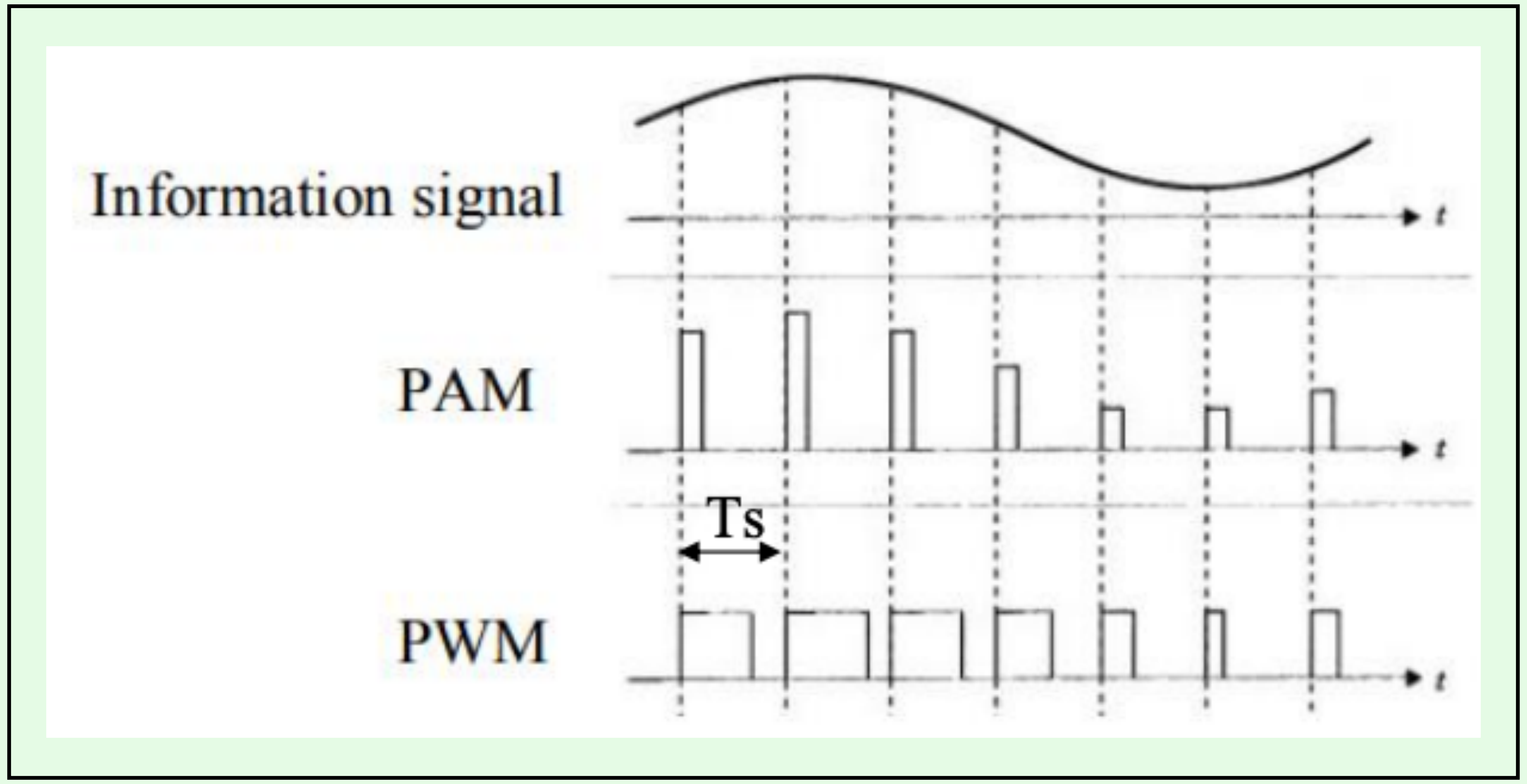
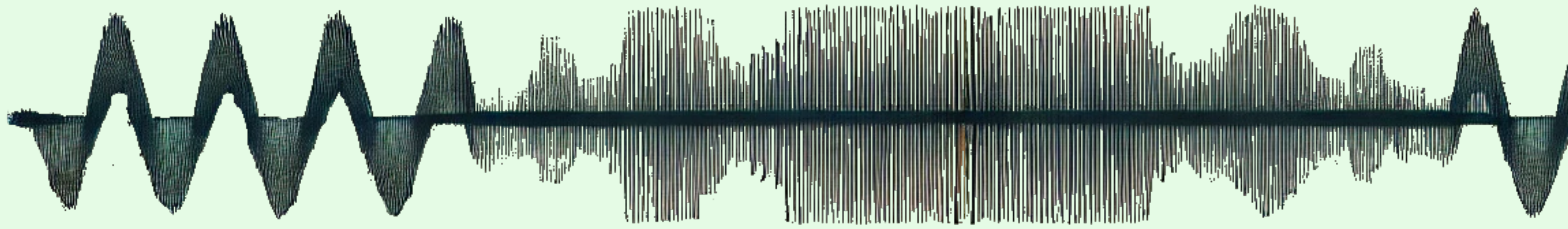
IMPULSIVE: *PULSE AMPLITUDE*



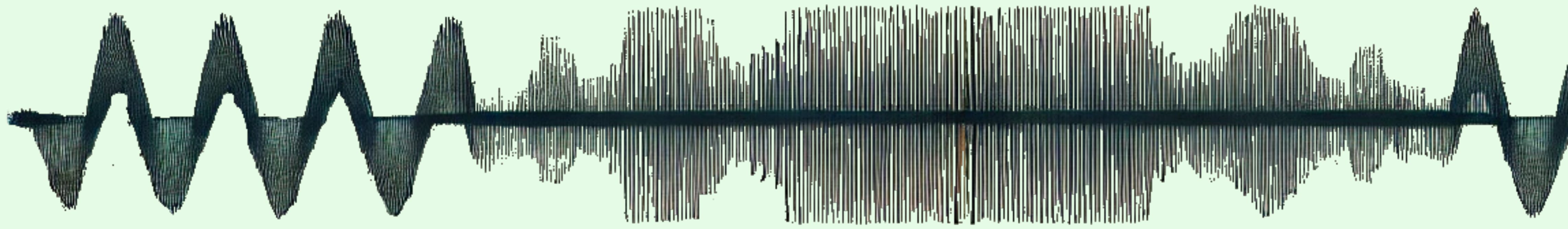
PAM = Modulate the amplitude of pulses to convey information.
PWM = Modulate the duty cycle of pulses to convey information.

IMPULSIVE: *PULSE AMPLITUDE*



- **Disadvantages**
  - Noise greatly affects amplitude, which houses the signal's information.
  - Since each pulse only carries amplitude information more bandwidth is required for data transmission then compared to other modulation formats.
- **Advantages**
  - Suitable for channels were bandwidth is less restricted.
  - Simple to implement, uses a low-pass filter to smooth out the pulse at demodulator.

IMPULSIVE: *PULSE AMPLITUDE*



- Telecommunication Systems

  Utilized in optical fiber communication systems.

  Implemented in IEEE Std 802.3-2018 Standard for Ethernet

SECTION FOUR

55. Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 10GBASE-T

55.1.1 Objectives

The objectives of 10GBASE-T are as follows:

a) Support full duplex operation only
b) Support star-wired local area networks using point-to-point links and structured cabling topologies
c) Support a speed of 10 Gb/s at the MAC/PLS service interface
d) Support copper medium from ISO/IEC 11801:2002, with appropriate augmentation as specified in 55.7
e) Support operation over 4-connector structured 4-pair, twisted copper cabling for all supported distances and Classes
f) Define a single 10 Gb/s PHY that would support links of up to 100 m on 4-pair balanced copper cabling as specified in 55.7
g) Preserve the IEEE 802.3/Ethernet frame format at the MAC client service interface
h) Preserve minimum and maximum frame size of the current IEEE 802.3 standard
i) Support Auto-Negotiation (Clause 28)
j) Meet CISPR/FCC Class A EMC requirements
k) Support a BER of less than or equal to 10^{-12} on all supported distances and Classes
l) Support a EEE capability as part of Energy-Efficient Ethernet (Clause 78)

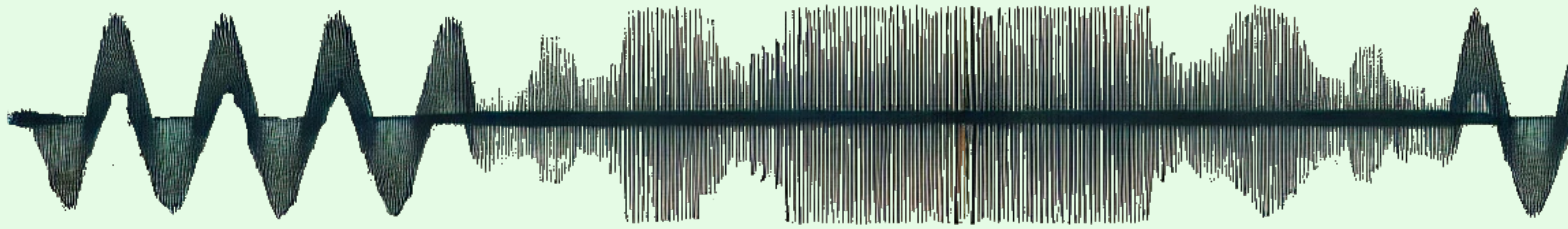
IEEE Std 802.3-2018, IEEE Standard for Ethernet
SECTION EIGHT

122. Physical Medium Dependent (PMD) sublayer and medium, type 200GBASE-FR4, 200GBASE-LR4, 400GBASE-FR8, and 400GBASE-LR8

122.1 Overview

This clause specifies the 200GBASE-FR4, 200GBASE-LR4, 400GBASE-FR8, and the 400GBASE-LR8 PMDs together with the single-mode fiber medium. The optical signals generated by these four PMD types are modulated using a 4-level pulse amplitude modulation (PAM4) format. When forming a complete Physical Layer, a PMD shall be connected to the appropriate PMA as shown in Table 122–1, to the medium through the MDI and optionally with the management functions that may be accessible through the management interface defined in Clause 45, or equivalent.

IMPULSIVE: *PULSE AMPLITUDE*



10GBASE-T

To achieve 10 Gb/s transmission rates, 2500 Mb/s sent down four pairs of balanced cabling.

Uses 16-level PAM with a modulation rate of 800 Megasymbol per second on each pair, with a symbol period equal to 1.25 [ns].

PAM enables IEEE's Energy-Efficient Ethernet (EEE) Clause 78, by utilizing a Low-Power Idle (LPI) mode.

ROADMAP

- *Types of Modulation*
    - ~~Analog: Single Sideband~~
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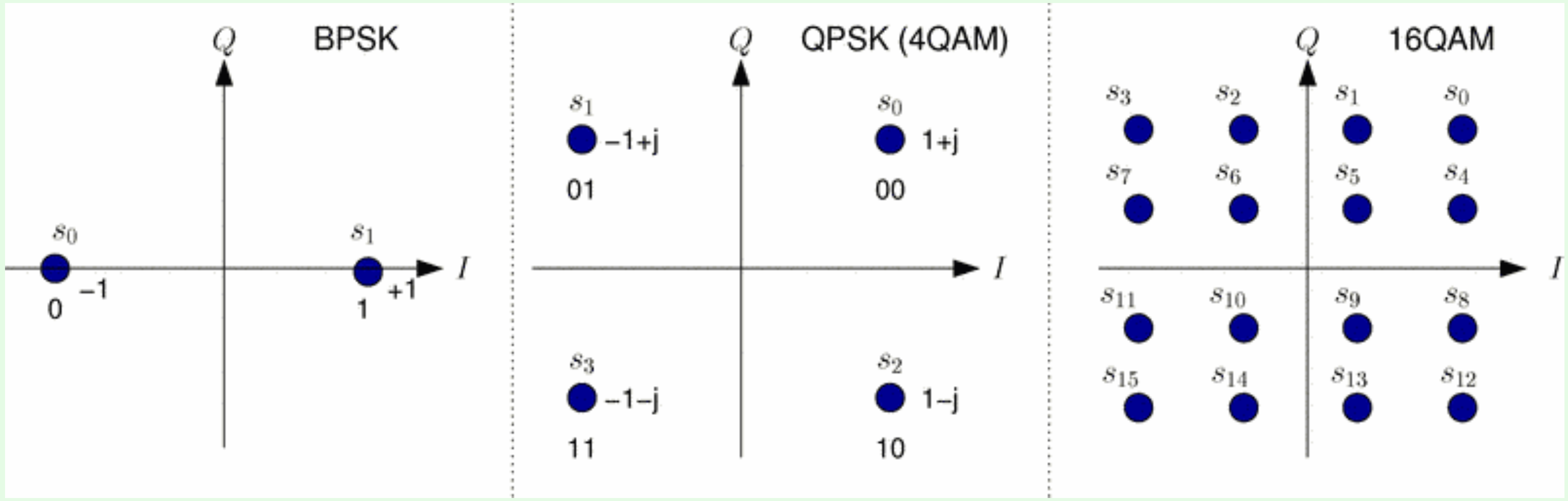
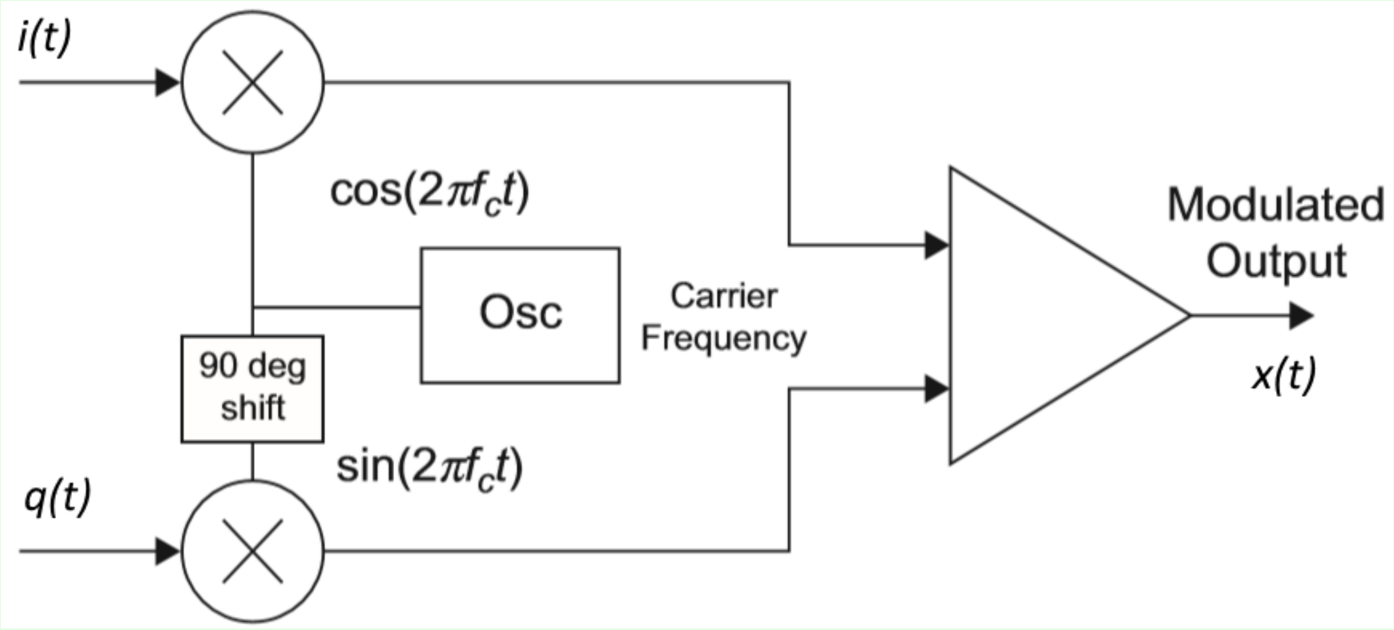
- *Questions and Comments*

NUMERICAL: *PSK - QAM*

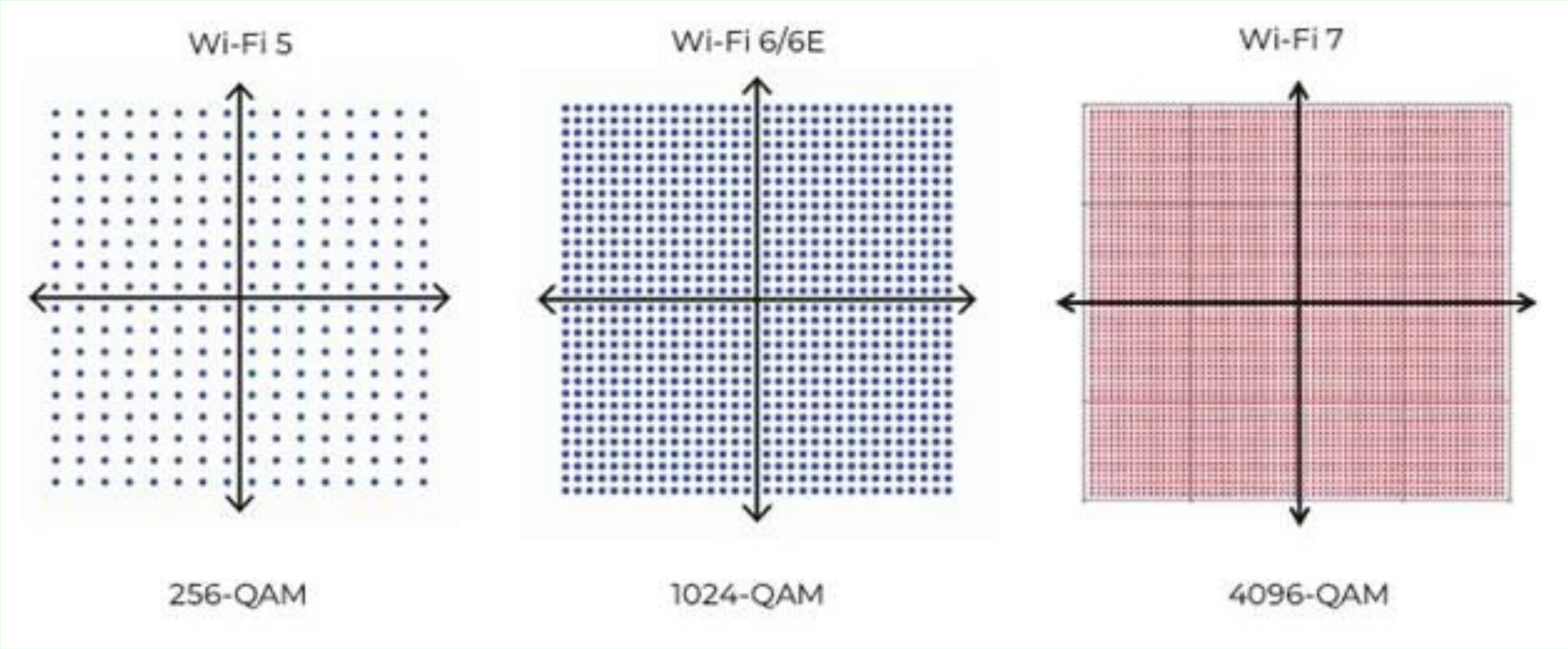




Phase Shift Keying, discrete levels are associated with specific states.

Constellation Diagrams indicate a format's resiliency to noise, more space, more resilient!

NUMERICAL: *1024-QAM*



IEEE Std 802.11ax-2021
IEEE Standard for Information Technology—Local and Metropolitan Area Networks—Specific Requirements—
Part 11: Wireless LAN MAC and PHY Specifications—
Amendment 1: Enhancements for High Efficiency WLAN

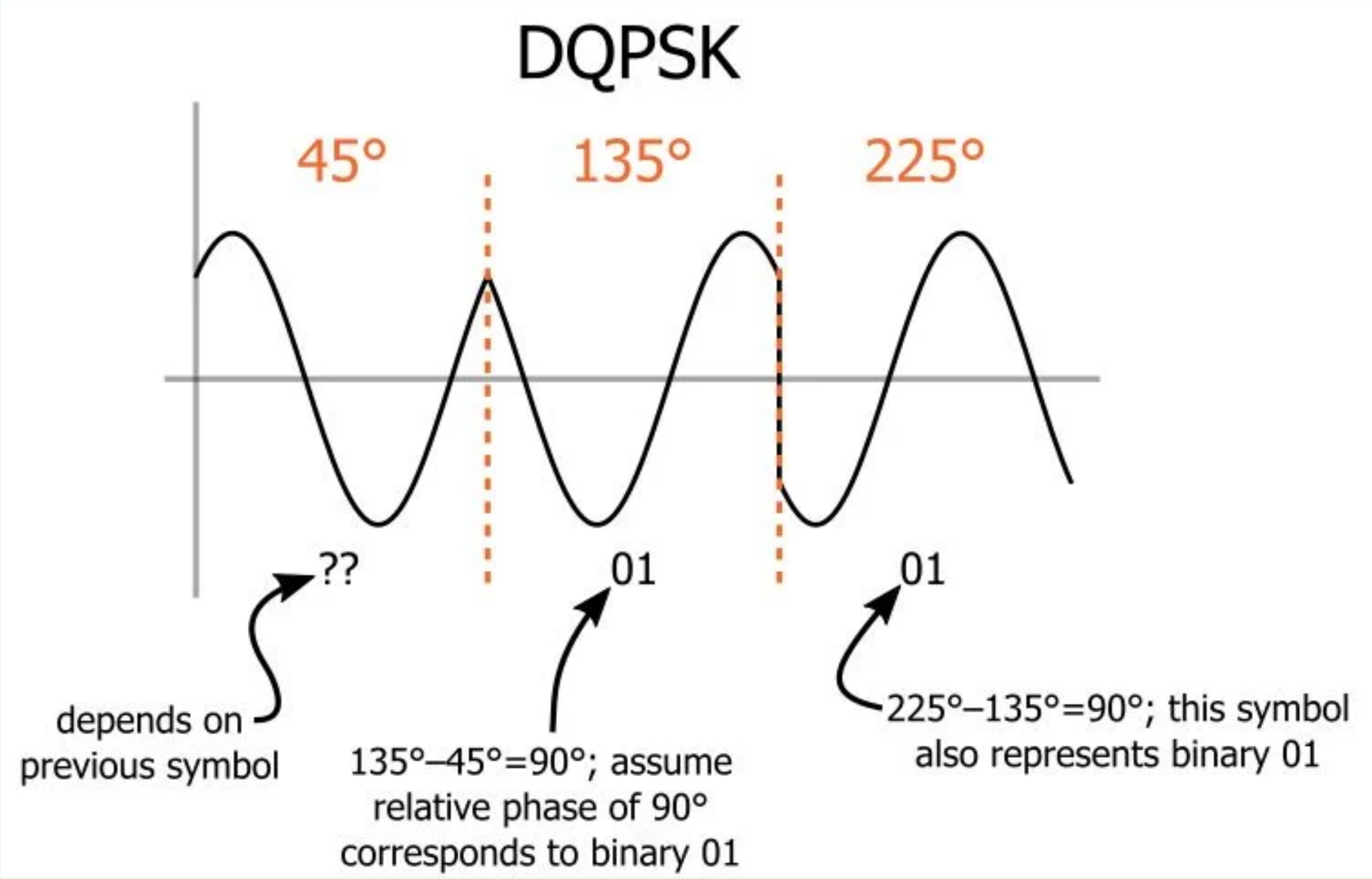
high-efficiency (HE) modulation and coding scheme (HE-MCS): A specification of the HE physical layer (PHY) parameters that consists of modulation order (BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM) and forward error correction (FEC) coding rate (1/2, 2/3, 3/4, 5/6) and that is used in an HE PHY protocol data unit (PPDU).

QAM Constellation Diagrams showcasing decreased noise tolerance from left to right.

Uses two carrier signals to modulate amplitude and phase, resulting in more symbols!

DOCSIS 4.0 deployed in 2017 uses 4096-QAM.

NUMERICAL: *DQPSK*



Data is encoded in the differential phase changes, instead of the absolute value of phase.

Typical shifts include 0°, 90°, 180°, and 270°.

NUMERICAL: *DQPSK*

Advantages

Removes the need for complex synchronization mechanisms, D means differential!

Like QPSK, it also transmits two bits per symbol, increasing bandwidth efficiency.

Disadvantages

Rapid changes can lead to errors in phase difference detection.

Differential encoding and decoding increases the complexity of the transmitter and receivers.

NUMERICAL: *DQPSK*

- **Satellite Communications**

  Requires signal integrity to be maintain over vast distances, in varying atmospheric conditions.

  Differential encoding is less susceptible to phase noise, doesn't require a coherent reference signal for demodulation.

- **IEEE Std 802.11b-1999**

HIGHER-SPEED PHYSICAL LAYER EXTENSION IN THE 2.4 GHz BAND — IEEE Std 802.11b-1999

The DBPSK encoder for the basic access rate is specified in Table 106. The DQPSK encoder is specified in Table 107. (In these tables, +jω shall be defined as counterclockwise rotation.)

Table 106—1 Mbit/s DBPSK encoding table

Bit input	Phase change (+jω)
0	0
1	π

Table 107—2 Mbit/s DQPSK encoding table

Dibit pattern (d0,d1) (d0 is first in time)	Phase change (+jω)
00	0
01	π/2
11	π
10	3π/2 (−π/2)

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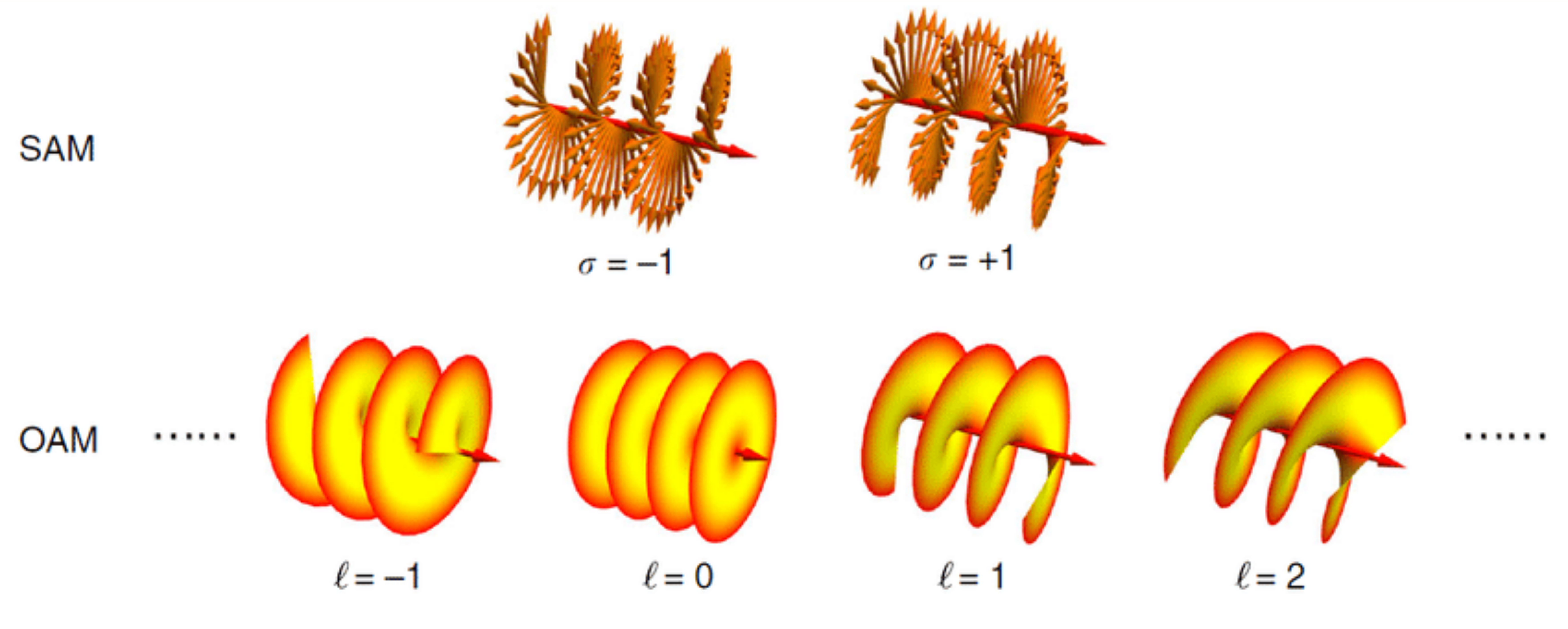
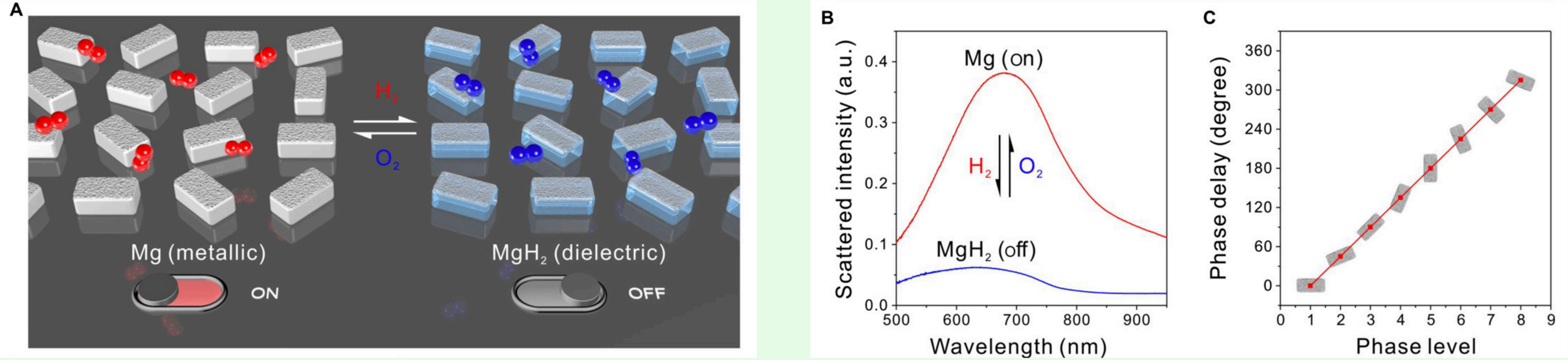
EXPERIMENTAL: *ORBITAL ANGULAR MOMENTUM*



SAM modulates the polarization state of the wave, OAM modulates the wavefront of the wave.

EXPERIMENTAL: *ORBITAL ANGULAR MOMENTUM*



A.) Hydrogen-responsive MG nanorods (200 nm X 80 nm X 50 nm) that are sandwiched between a Ti (5 nm)/ and Pd (10 nm) capping layer and a Ti (3nm) adhesion layer,

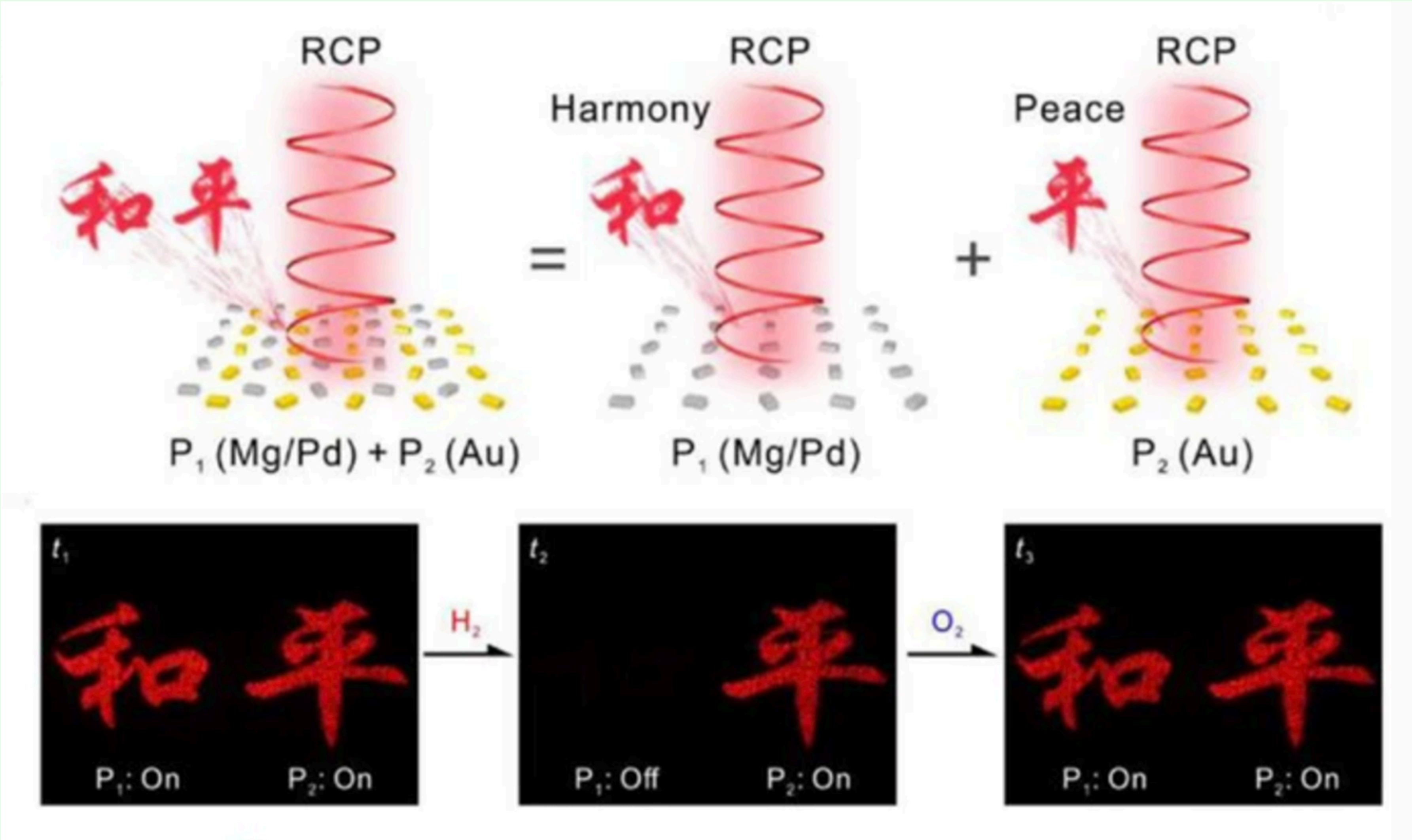
B.) The spectral measurement of a nanorod in Mg (ON) and MgH2 (OFF) states,

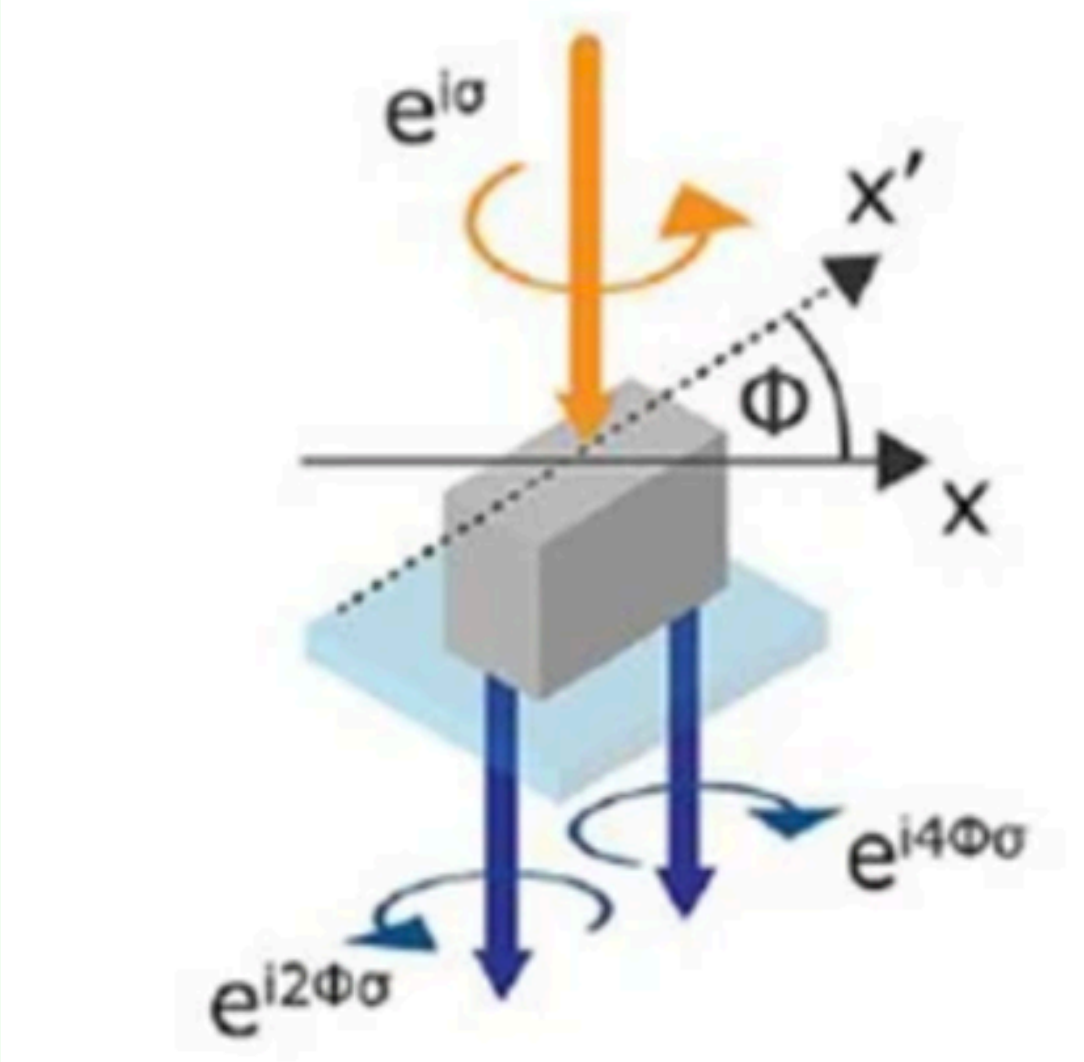
C.) Phase delay of Hyrdrogen-responsive MG nanorods. ©2018 Jianxiong Li, et al.

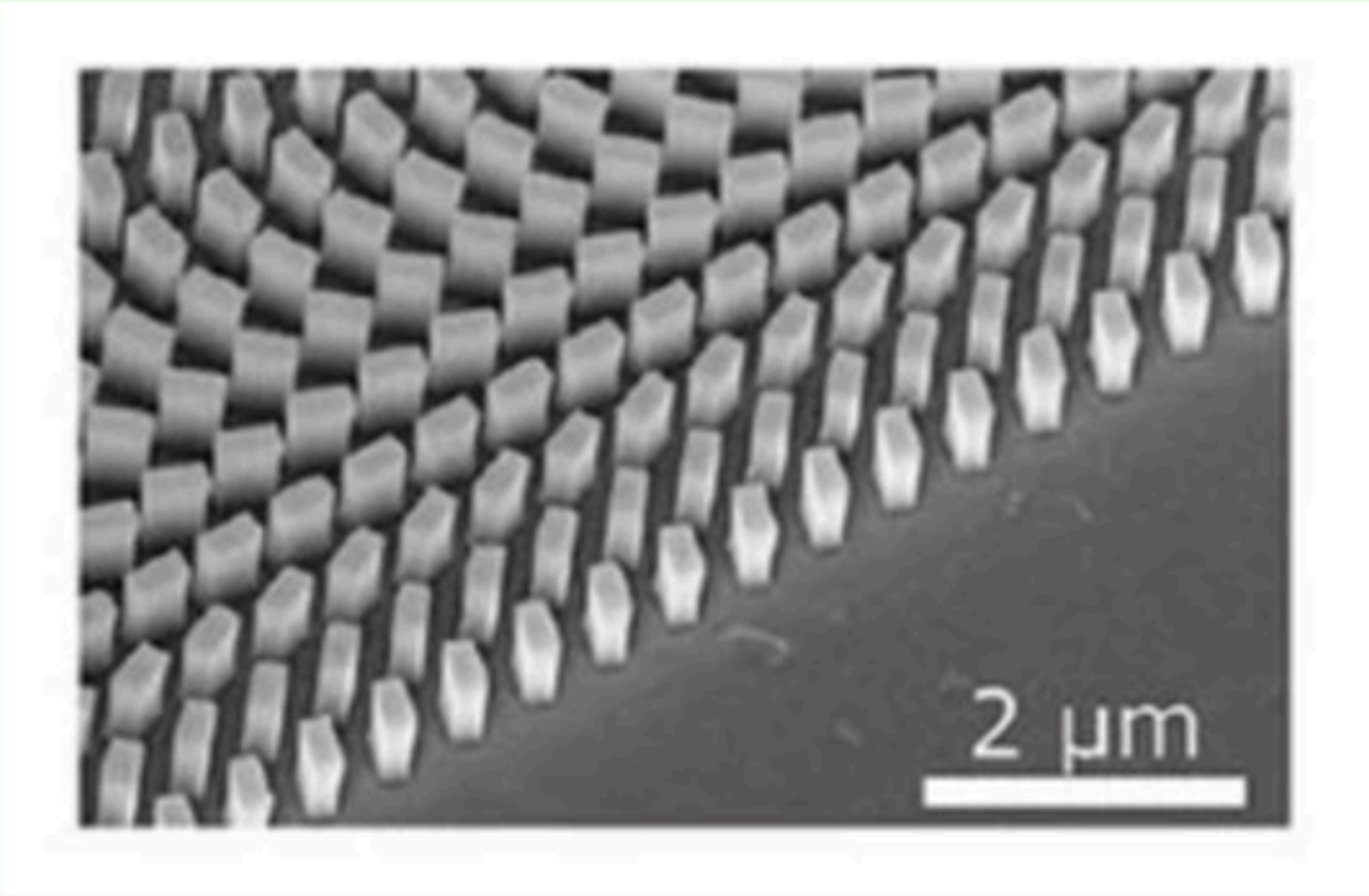
EXPERIMENTAL: *ORBITAL ANGULAR MOMENTUM*

- Metasurfaces

Metasurfaces are used to modulate the orbital angular momentum.







EXPERIMENTAL: *ORBITAL ANGULAR MOMENTUM*

- **Advantages**
  - Can coexist with other multiplexing techniques, increasing bandwidth efficiency.
  - Co-modulation of spin angular momentum (SAM) and OAM offer expanded capabilities without increasing bandwidth requirements.
- **Disadvantages**
  - Complex transmitters and receivers must be able to detect helical phase fronts accurately, significantly increasing the costs.
  - Alignment and atmospheric sensitivities greatly affect implementations over long distances.

EXPERIMENTAL: *ORBITAL ANGULAR MOMENTUM*

- **Deep Space Communications**
  - No atmospheric interference perfect for implementing OAM modulation.
  - Theoretically has an infinite number of orthogonal states that can be used, increasing channel capacity without the need for an increase in spectrum allocation.
- **Quantum Computing**
  - Being explored for use in quantum key distribution to provide enhanced security features.

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QUESTIONS AND COMMENTS?

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