可視光通信の建築や医療への利用可能性について
Exploring applications of visible light communication for the fields of architecture and medicine

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Abstract In recent years, with the wireless communication becomes more and more necessary in people's lives, there is a growing demands for wireless communication in radiosensitive area such as hospitals. Since Visible Light Communication (VLC) can avoid harmful effects on human health and does not interfere to medical electric equipment, it becomes a good candidate for indoor wireless communication in radiosensitive area. In addition, compare to radio signal, which has been widely used, visible light has good directivity. Moreover, LEDs can be used for both lighting and communication in the same time, and visible light can be received by image sensors in all kind of cameras. Consequently, besides medicine filed, VLC is a good choice in the architecture industry. For example, a home network system can be constructed with power line communications (PLC) and VLC without adding new communication cables. Moreover, positioning system, three-dimensional measurement of architecture can be conducted utilizing VLC and image-processing technology. This talk covers the VLC history, the modulation method, the application of VLC for the fields of architecture and medicine. The latest research results will be introduced related to the research of improving efficiency of these applications.

Keywords: Visible Light Communication, Modulation scheme, Architecture, Medicine, Image sensor, Image processing

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Exploring Applications of Visible Light Communication for the Fields of Architecture and Medicine

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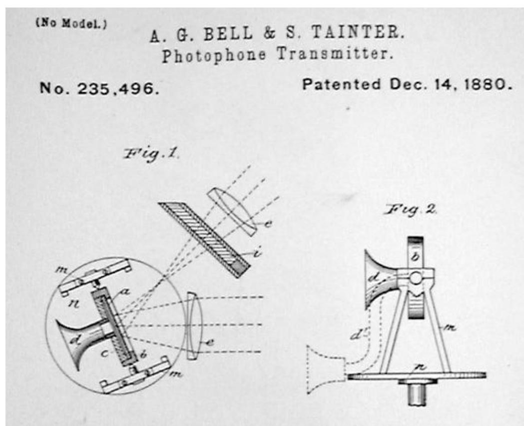
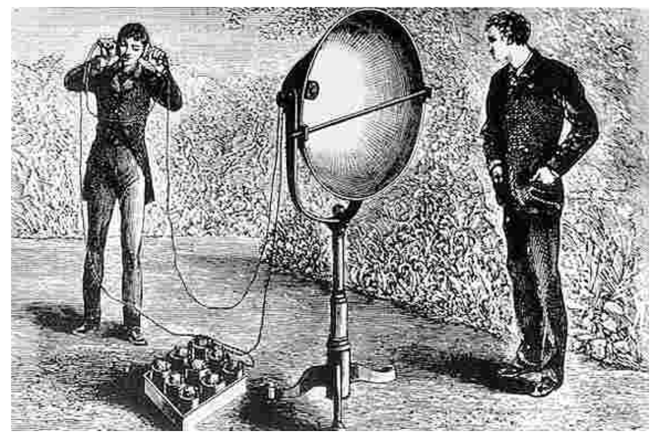
History of Optical Wireless Communication

The use of optical emissions to transmit information has been used since c.
(Fire beacons, Smoke signals)

Early 1790's, Claude Chappe invented the optical telegraph

1880 Alexander Graham Bell demonstrated the photophone





1960s
Invention of laser

1970s
Free Space Optical (FSO) mainly used in secure military applications

1979
Indoor OWM systems – F R Gfeller and G Bapst

History of Optical Wireless Communication

1993
Open standard for IR data communication – The Infrared Data Association (IrDA)

2003
The Visible Light Communications Consortium (VLCC) – *Japan*

2008
Global standards for home networking (infrared and VLC technologies) – “Home Gigabit Access” (OMEGA) Project – *EU*

2009
IEEE802.15.7 – standard on VLC

Refer to:

S . Rajbhandari, “Optical Wireless Communications System and Channel Modelling with MATLAB”, CRC Press 2012,Print ISBN: 978-1-4398-5188-3

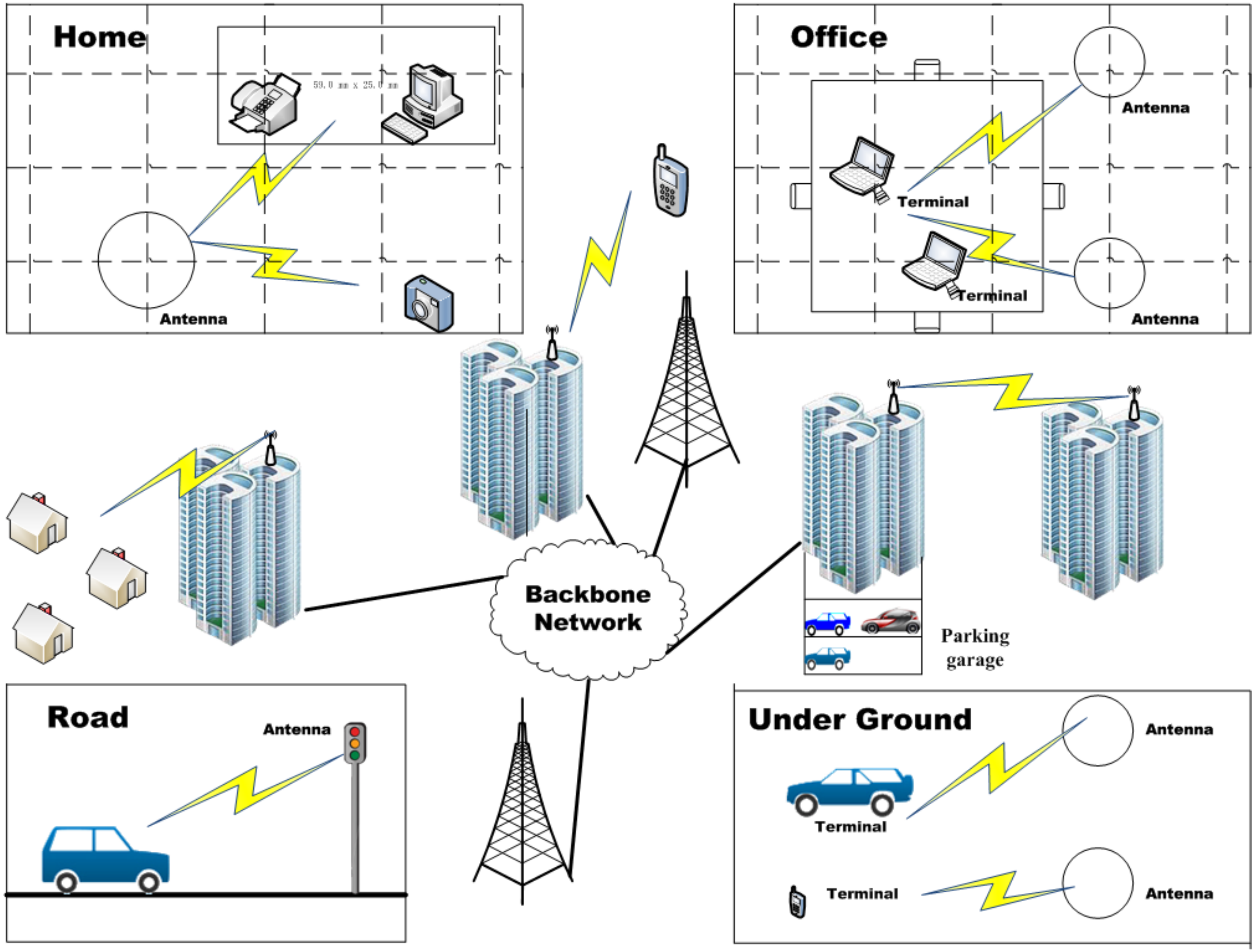
Comparison between RF and OWC

Property of Medium	RF	OWC
Bandwidth regulated	Yes	No
Passes through walls	Yes	No
Multipath distortion	Yes	Yes
Path loss	High	High
Dominant noise	Other users	Background light
Input X(t) represents	Amplitude	Power

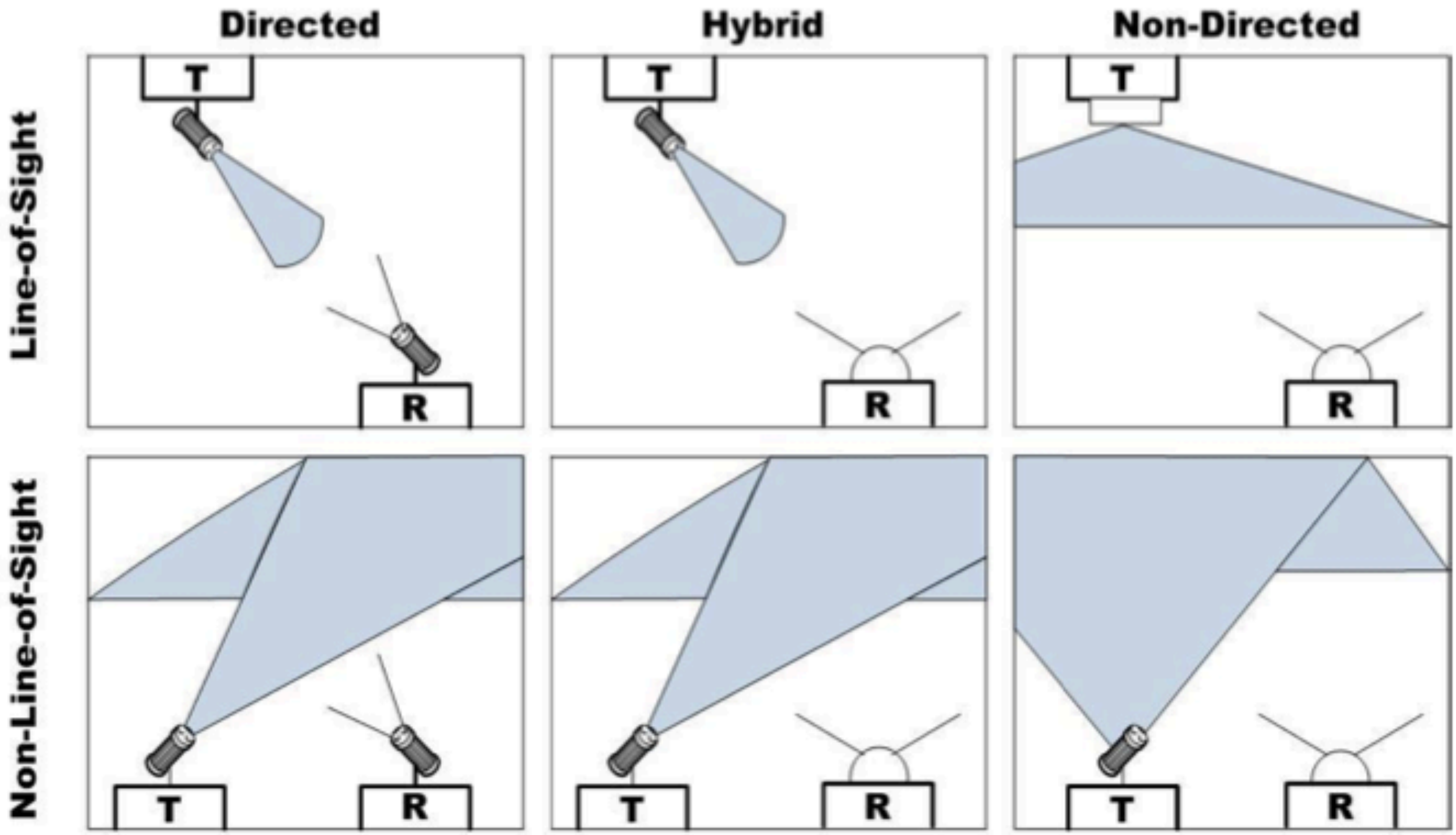
RF : Radio Frequency　　OWC : Optical Wireless Communication

Refer to:
M. Kahn and J. R. Barry, "Wireless infrared communications," *Proceedings of the IEEE,* vol. 85, No. 2, pp. 265-298, 1997.

Application of Optical Wireless Communications



Classification of Optical Links



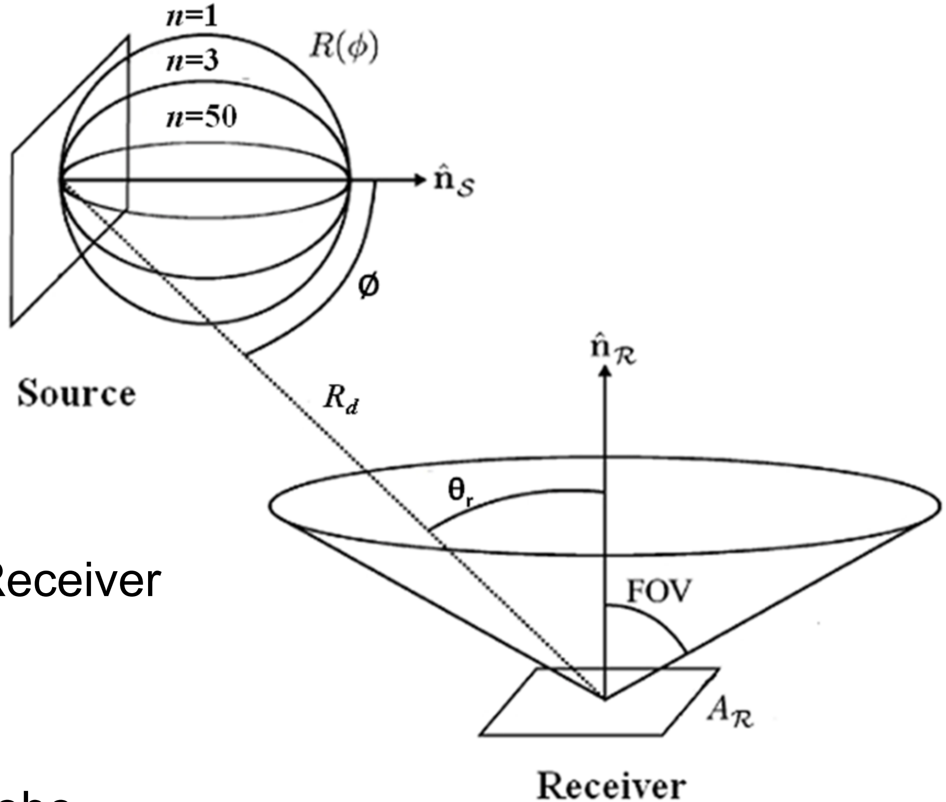
Refer to:
M. Kahn and J. R. Barry, "Wireless infrared communications,“ *Proceedings of the IEEE,* vol. 85, No. 2, pp. 265-298, 1997.

Lambertian Model

$$P_r = \frac{1}{R_d^{\ 2}} \times \frac{n+1}{2\pi} P_t \cos^n(\phi) \times A_R \cos(\theta_r) rect(\frac{\theta_r}{FOV})$$

$$rect(x) = \begin{cases} 1, & |x| \le 1 \\ 0, & |x| > 1 \end{cases}$$

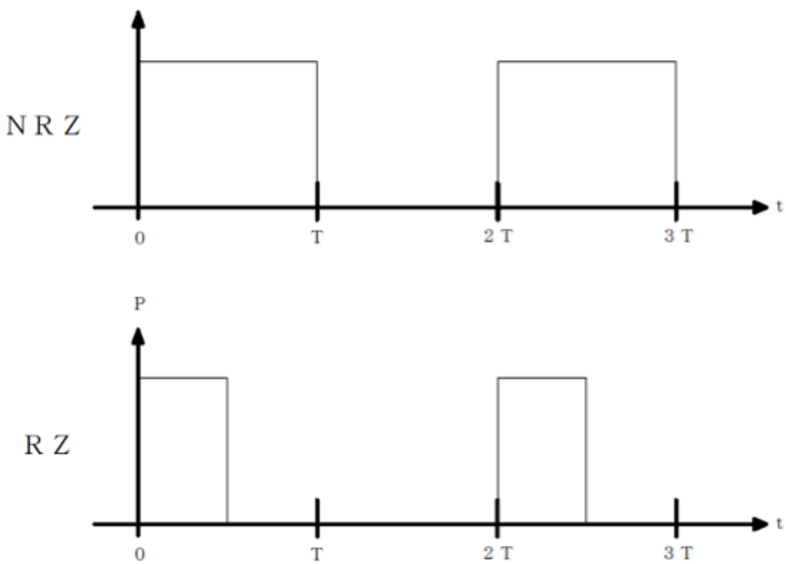
$$n = \frac{\ln(1/2)}{\ln(\cos hpa)}$$



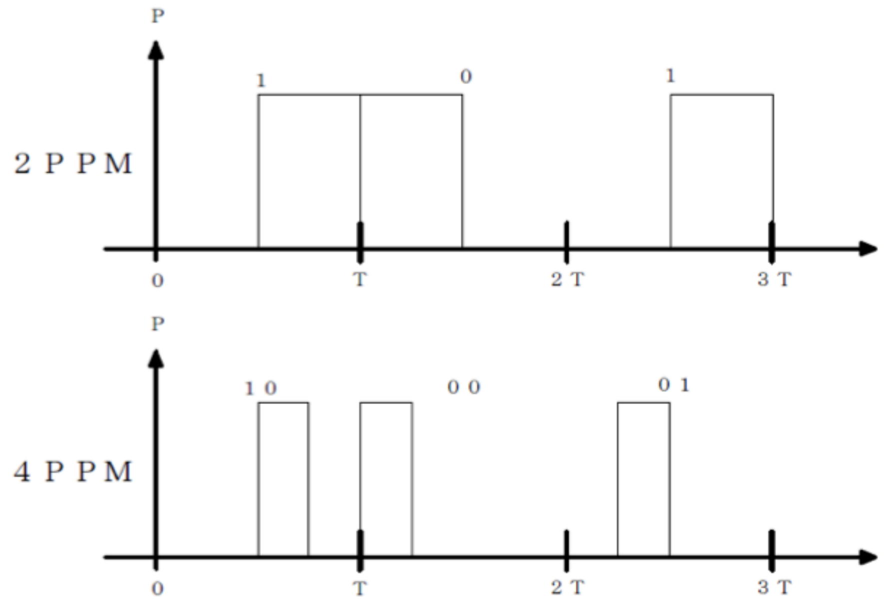
P_r : Received Power
R_d : Distance between source and Receiver
P_t : Transmitted Power
A_R : Receiver Area
FOV : Field of view angle
n : Mode number of the radiation lobe
hpa : Half Power angle

Modulation Methods

On-off Keying (OOK)

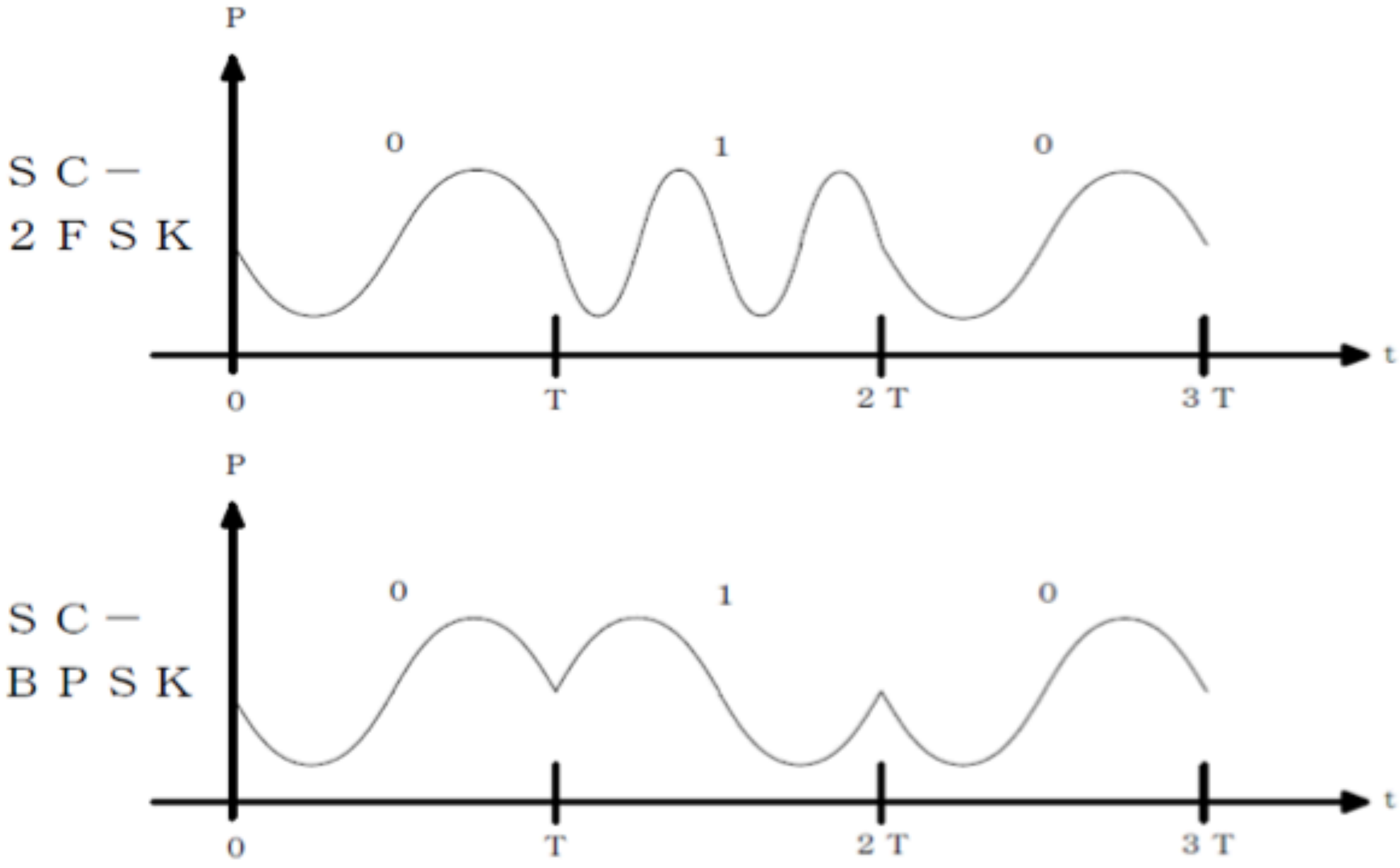


Pulse-position modulation (PPM)

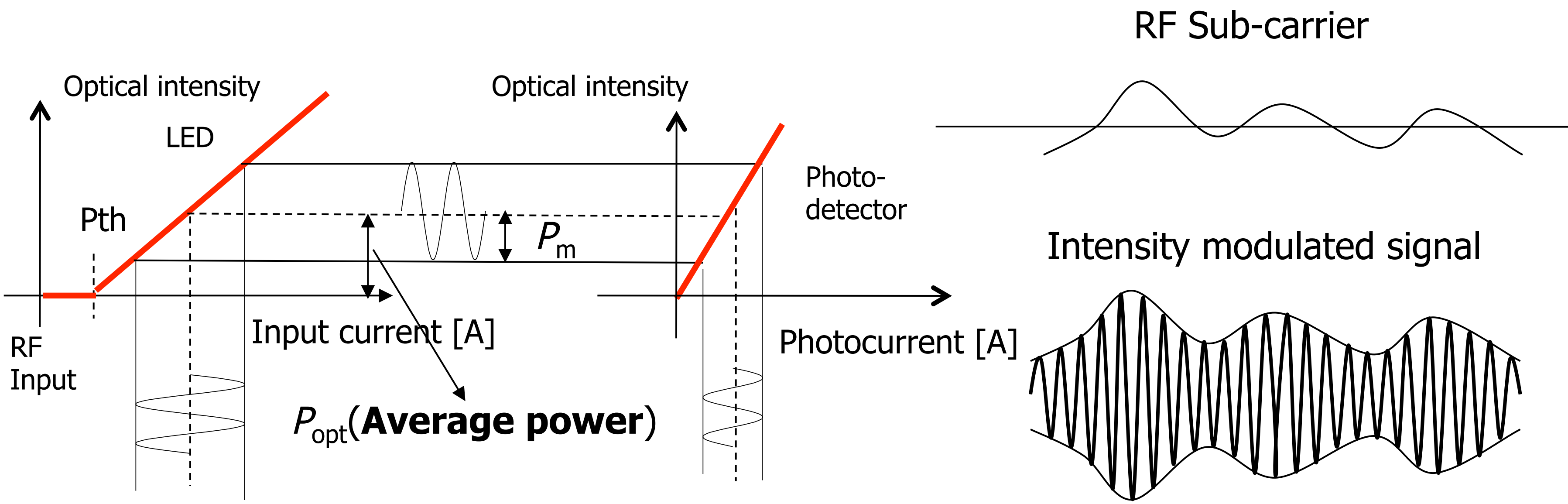


Modulation Methods

Sub-carrier Modulation



Intensity Modulation and Direct Detection (IM/DD)



Modulation index (Modulation depth) m : P_m/P_{opt}

RF Current ∝ Optical Power

The RF signal received by the relay station is denoted as S_{RF} , the optical signal after bias adjustment can be expressed as

$$P_t(t) = P_{opt}\{1 + m \cdot (S_{RF} + n_{RF})\}$$

P_{opt}: average radiation power of light emission element
n_{RF}: is an additive white Gaussian noise (AWGN) m: modulation index

Challenges for Visible Light Communication

Outdoor

- Difficult to deploy Point-to-Multi-Point Links
- Turbulence scintillation caused power fading
- Tracking necessary
- Tracking error caused power fading

Indoor

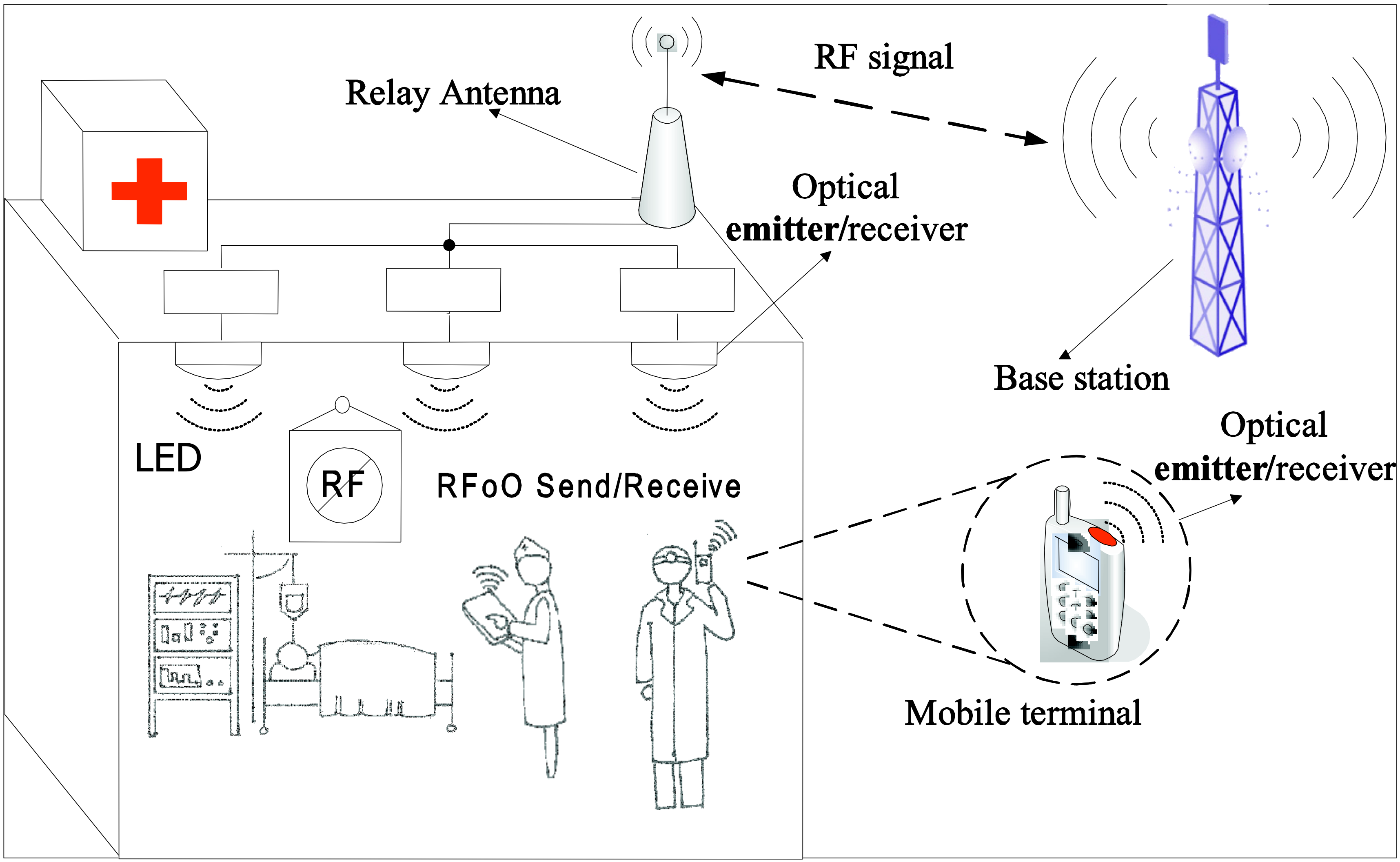
LOS link

- Tracking necessary
- No/Limited mobility
- Shadowing

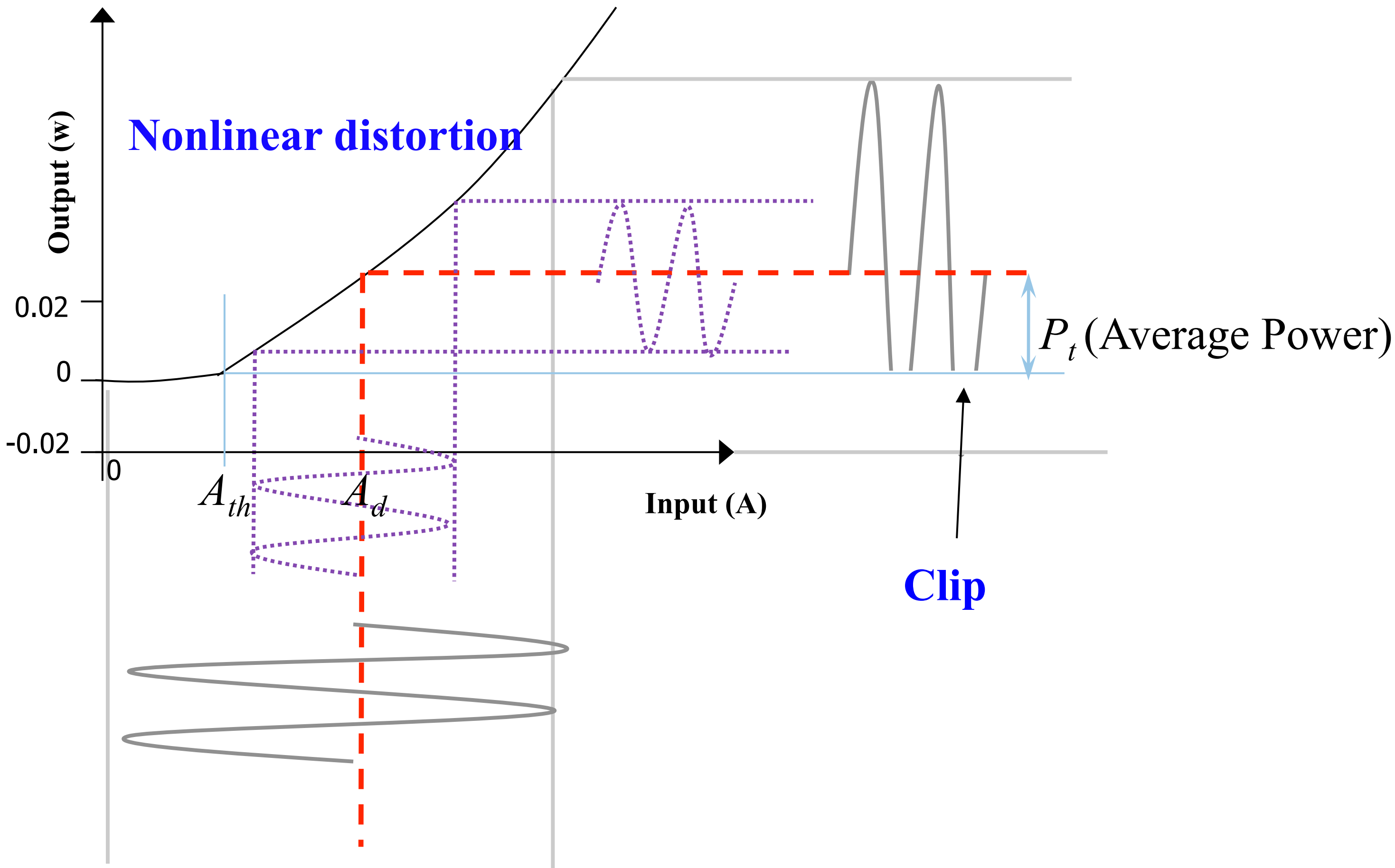
Diffuse Links

- High path loss
- Reflections
- Inter symbol interference (ISI)
- Limited Speed

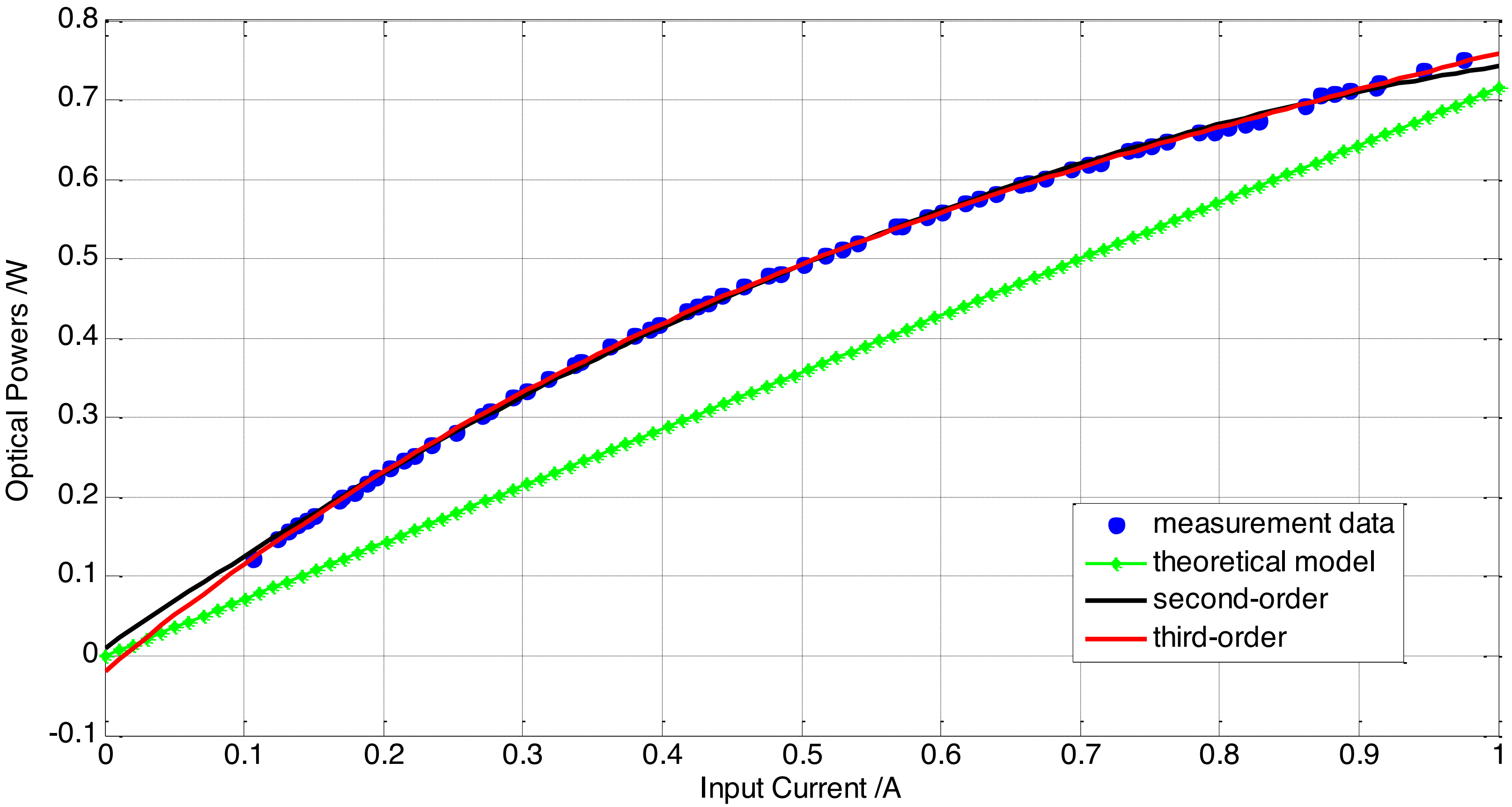
Applications for Medicine Area



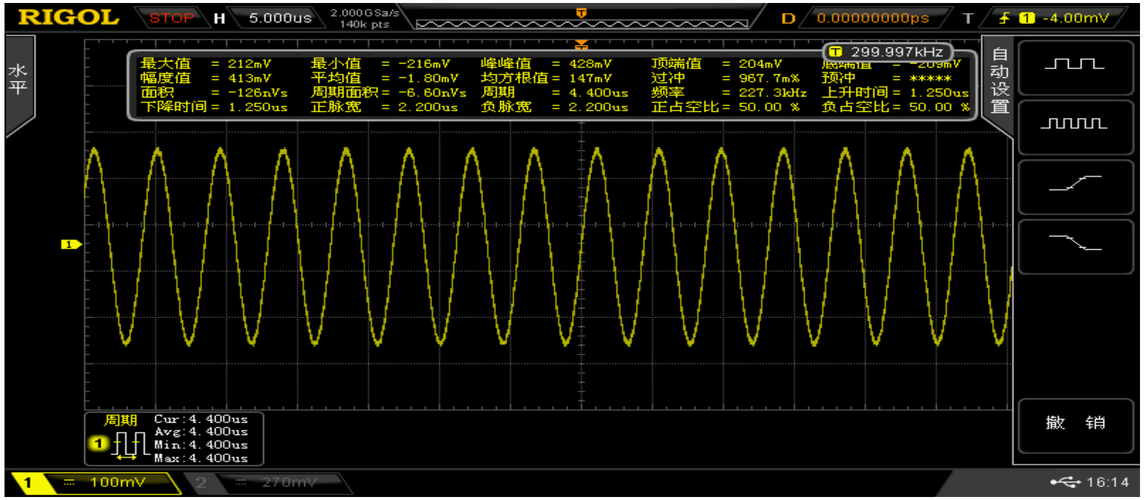
Output Character of Light Emitter



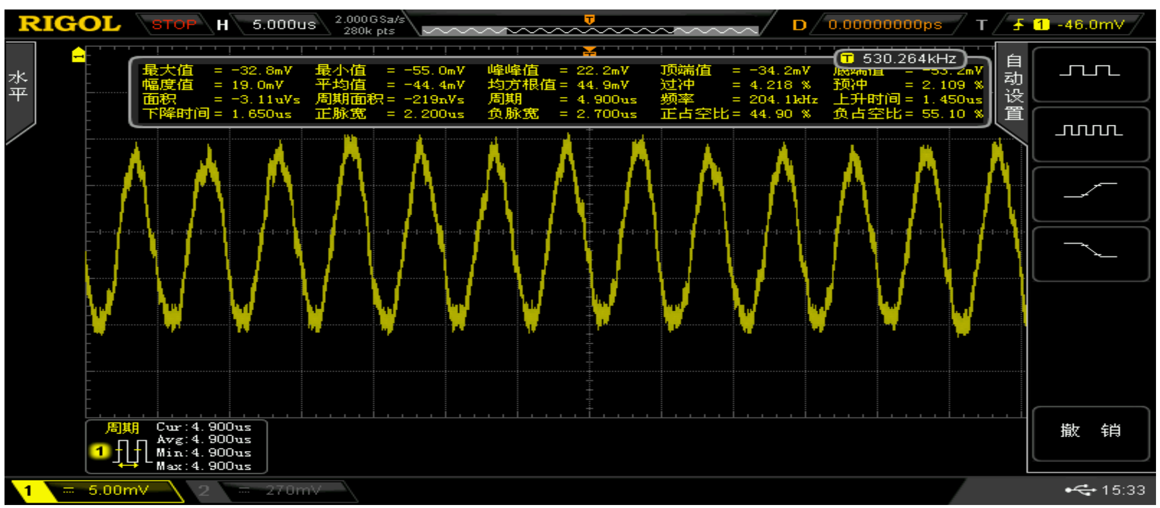
Experiment Results : LED Nonlinearity



Experiment Results

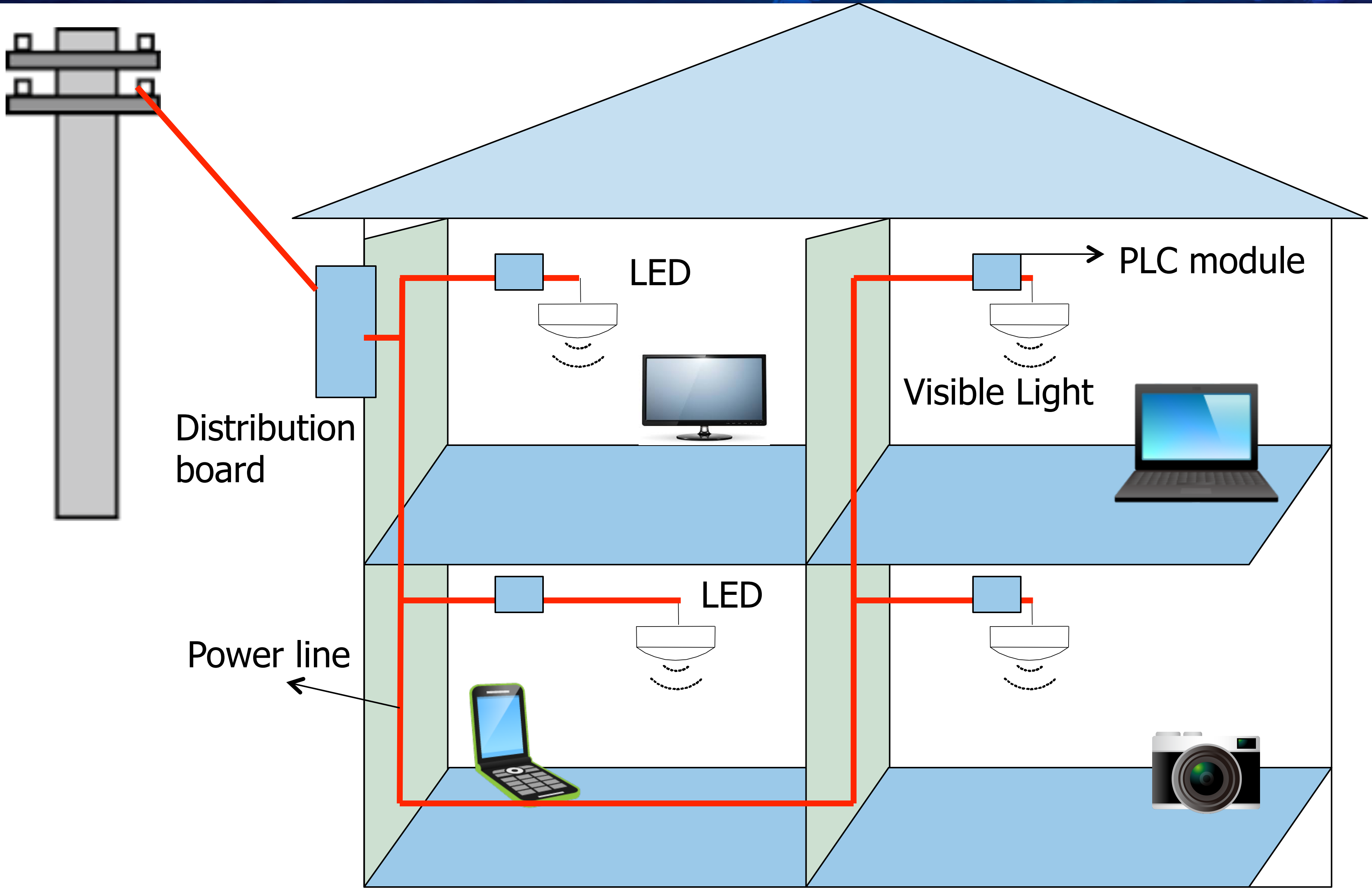


Transmitted FM signals

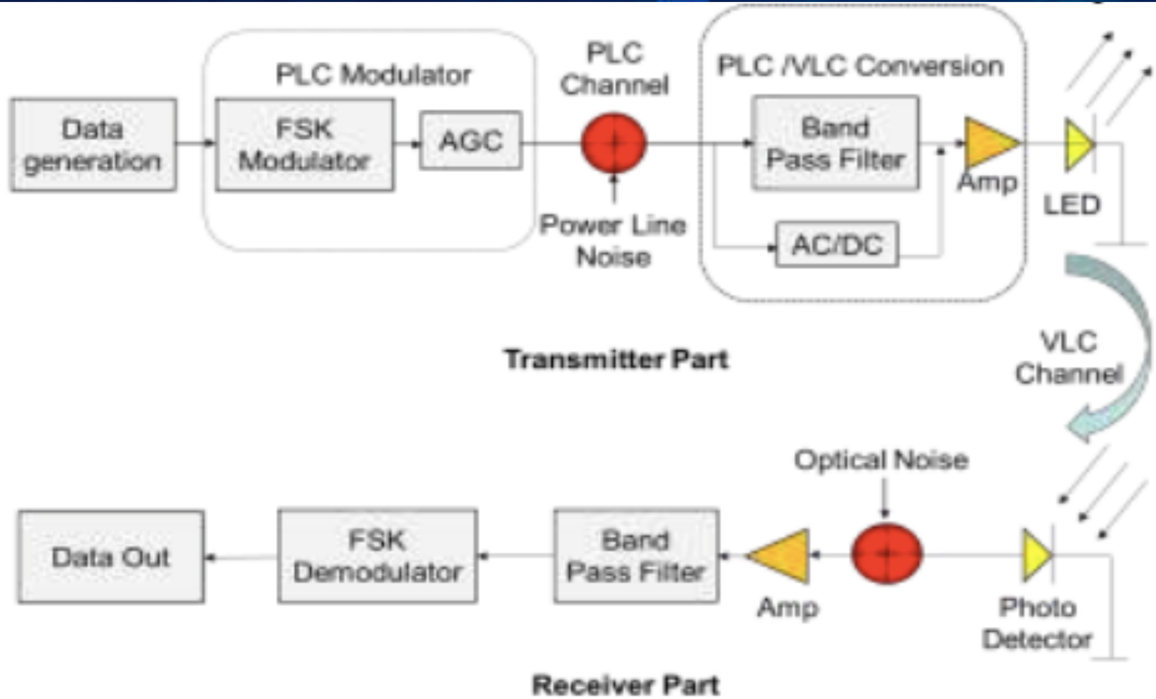


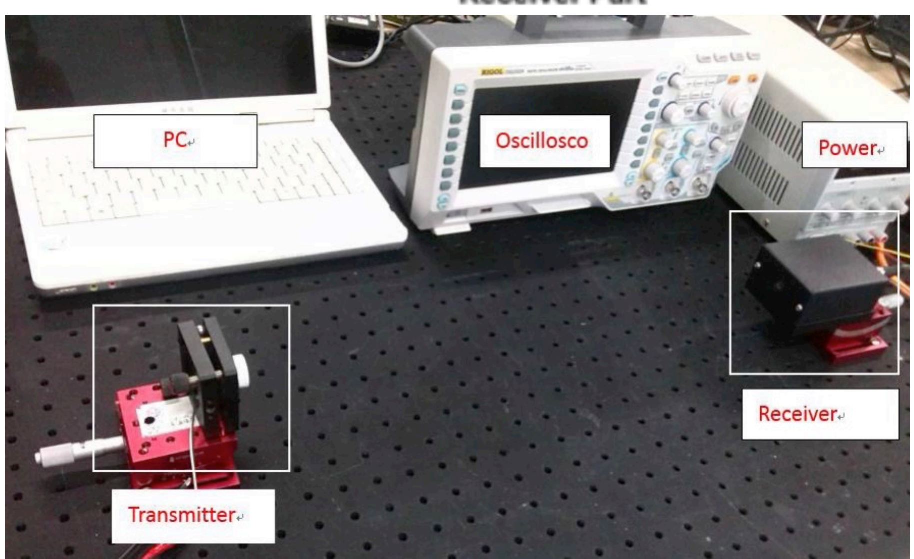
Received FM signals

Application of VLC and PLC



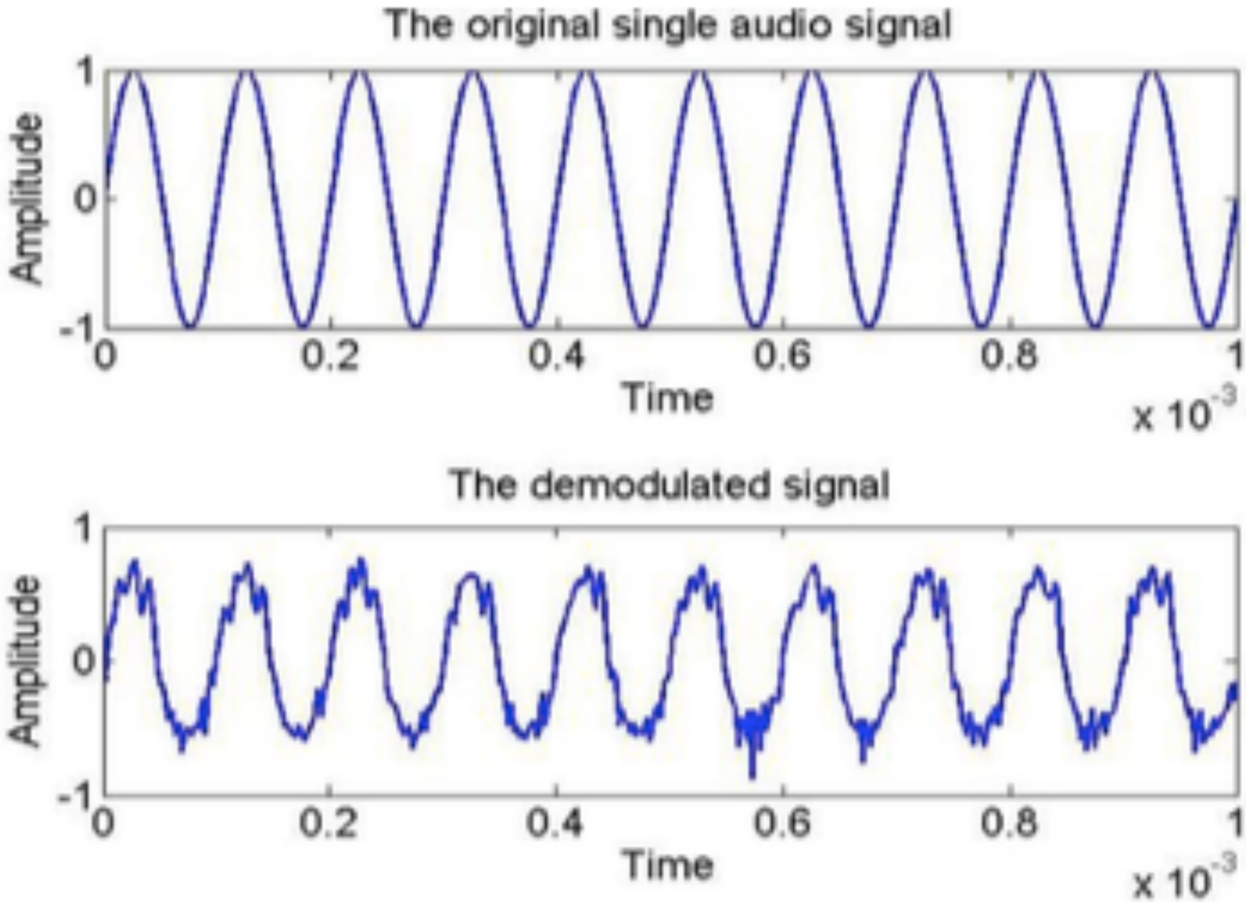
Experiment of FSK on Integrated System based on VLC and PLC



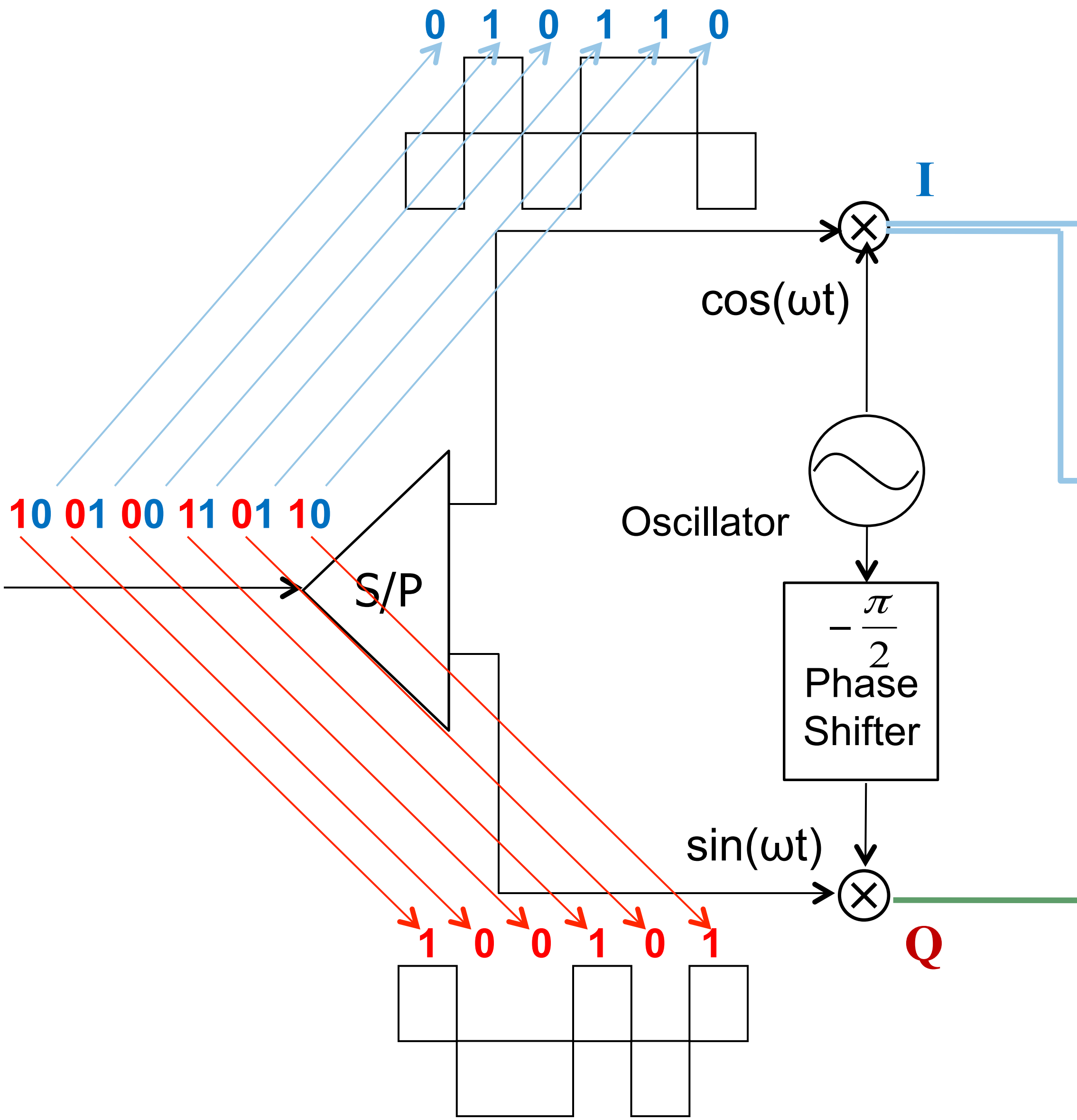


Experiment of FSK on Integrated System based on VLC and PLC

The Original Signal and the Demodulated Signal

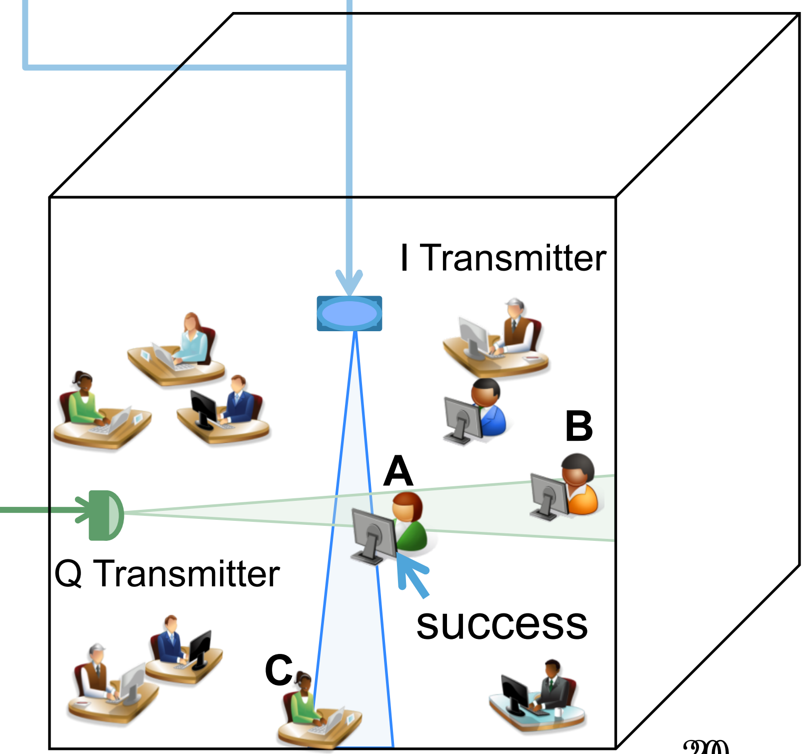


Position - Based Diversity Transmission Scheme



Application

- High security position based applications
- Indoor positioning

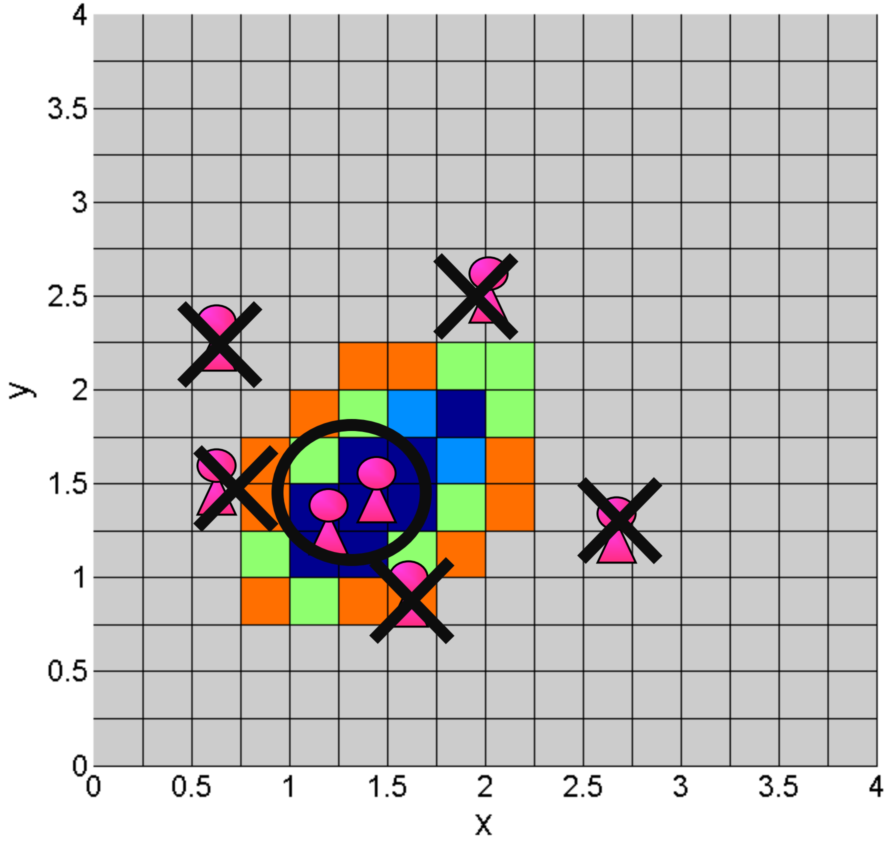


S/P: Serial/Parallel convertor

Service Area (one example)

n (beam index)= 1

Position- Based Scheme



Conventional QPSK

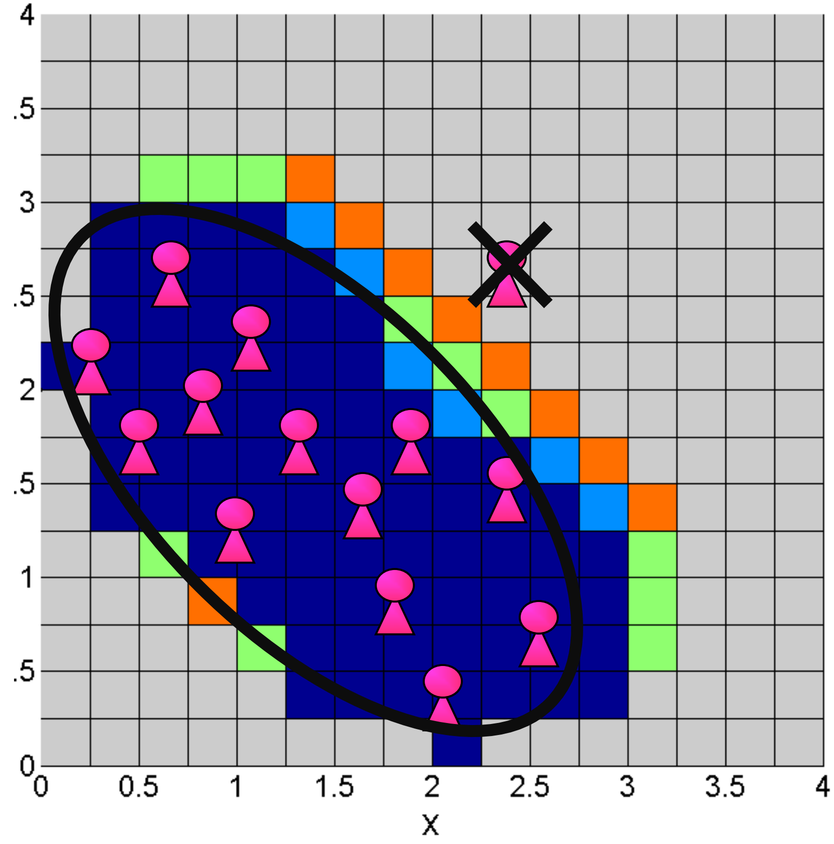
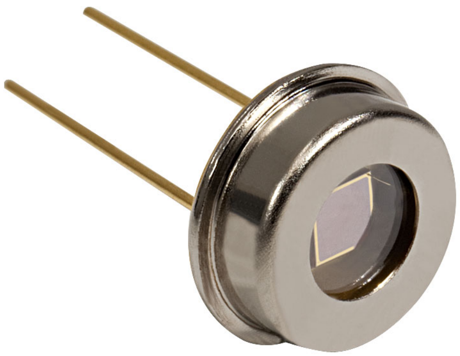


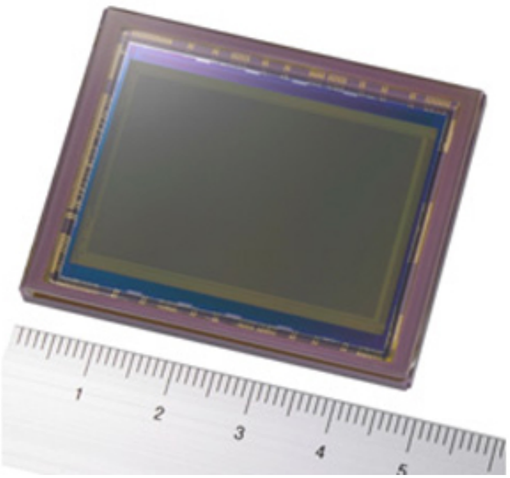
Image Sensor Communication

Photodiode

Image sensor

a group of a large amount of photodiode (pixel).

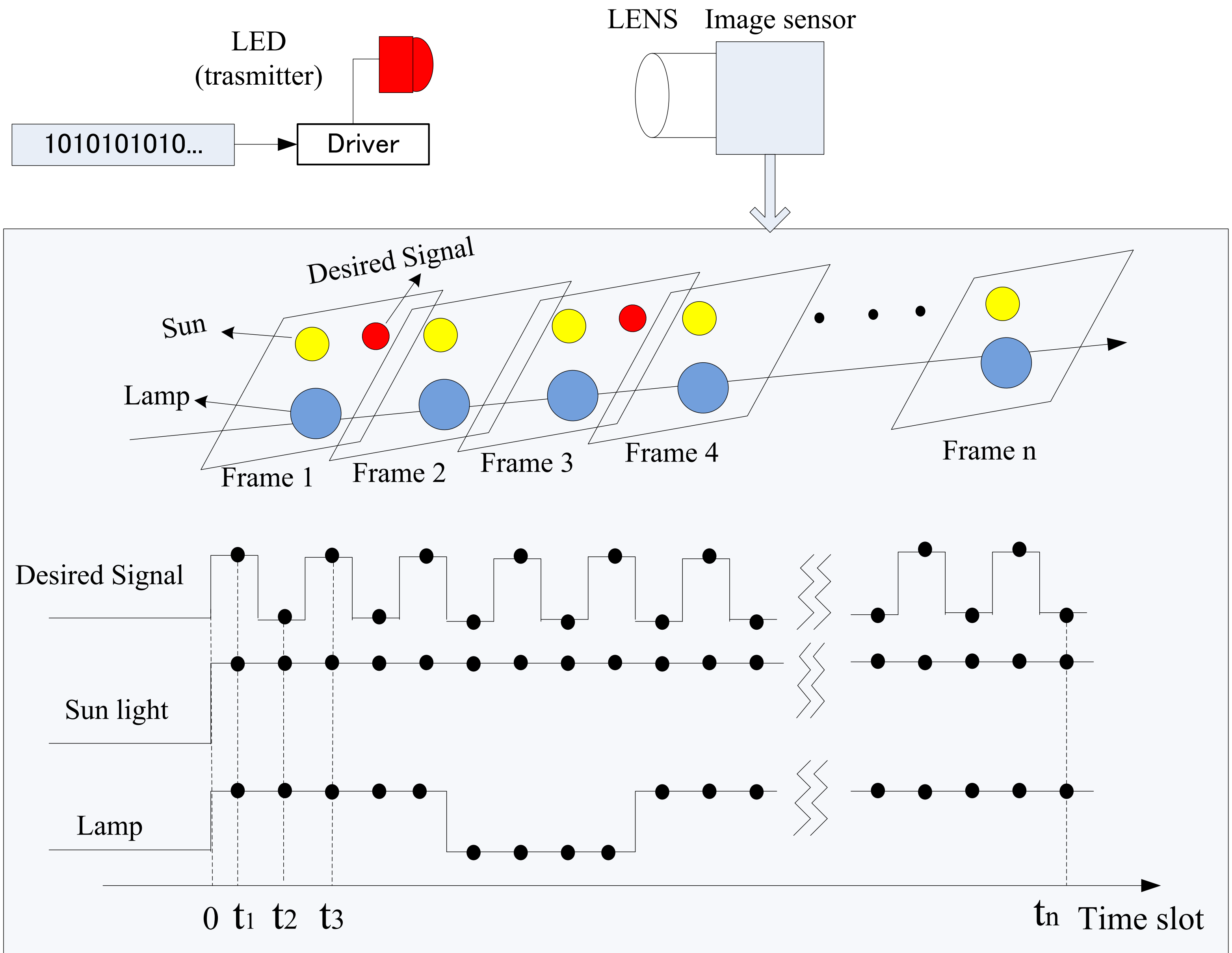




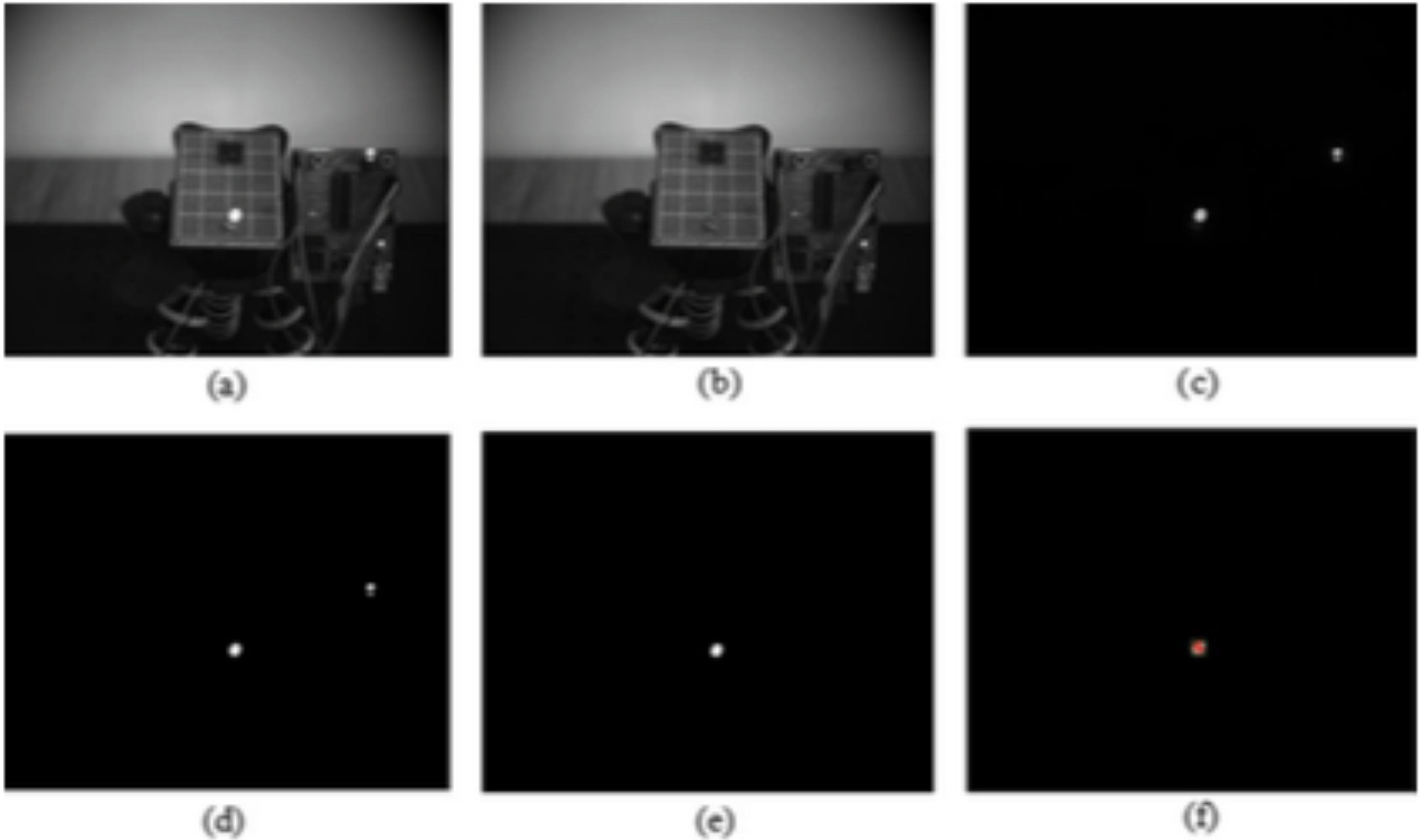
CMOS image sensor(Sony)

An ***image sensor*** is a device that coverts an optical image to an electric signal. It is used mostly in digital cameras and other imaging devices.

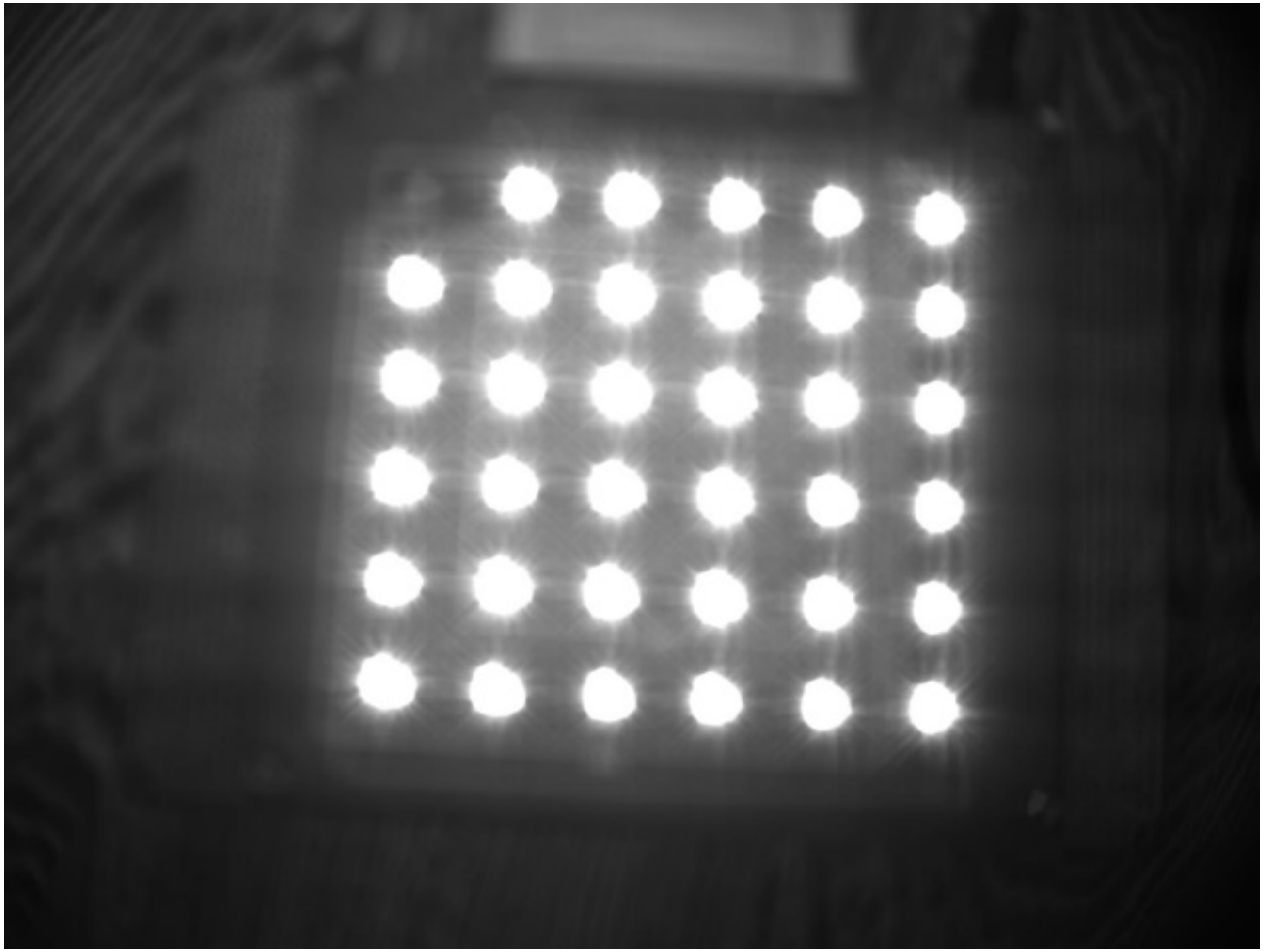
Model of the Image Sensor Communication



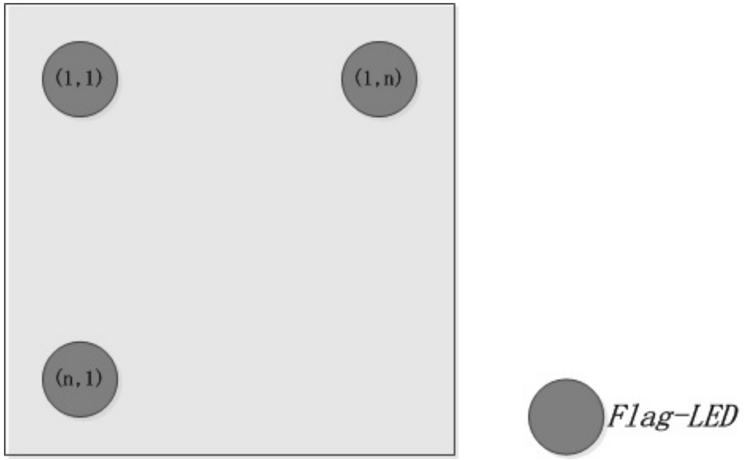
The Frame Difference Method

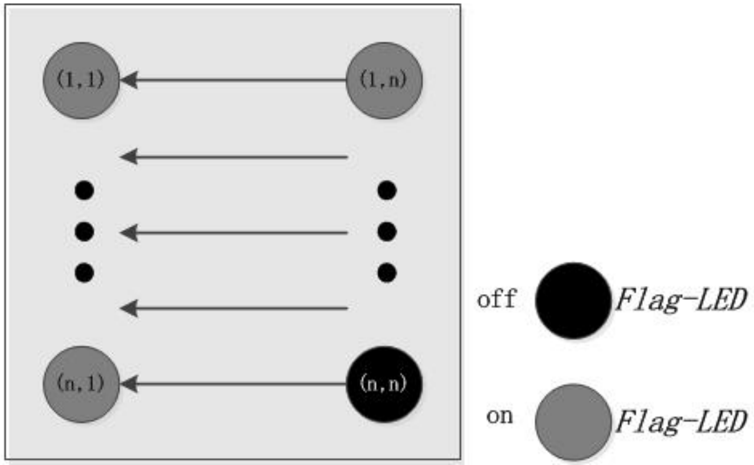


LED Array used for Indoor Positioning System



Indoor Positioning Systems

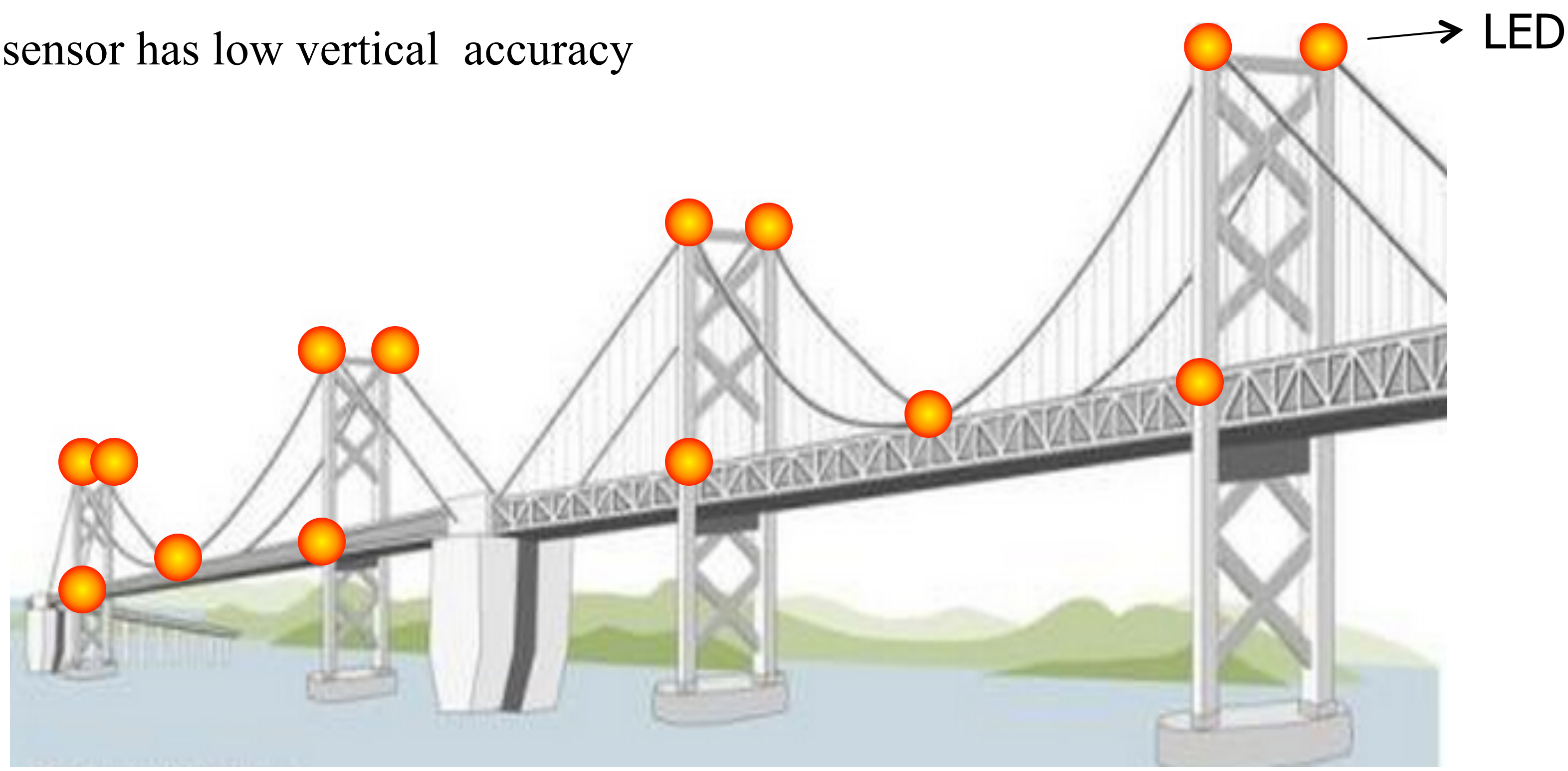


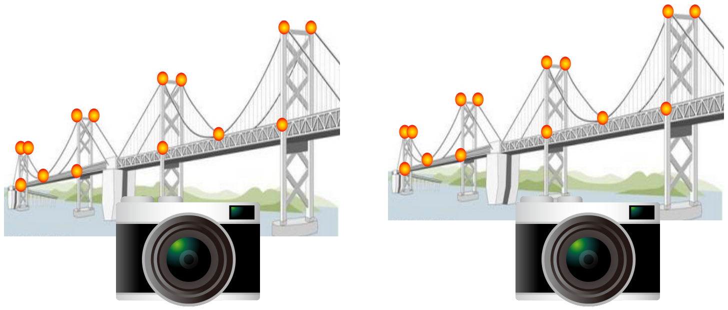


Flag-LED based LED array decode

Three-dimensional Position Measurement System Utilizing VLC and Image Processing Technology

GPS sensor has low vertical accuracy

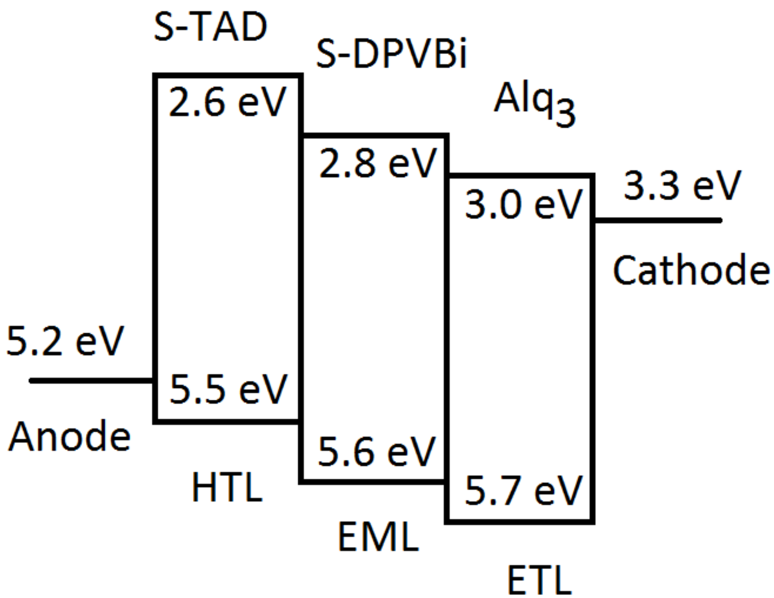


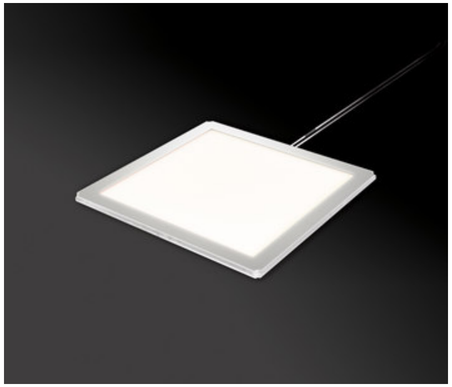


Organic LED

Organic LED: emits light using spontaneous emission in organic semiconductor

Anode	Hole-transport layer	Emission layer	Electron-transport layer	Cathode
Provide hole	Accelabrate hole transport	Recombine to from exiton / emission	Accelabrate electron transport	Provide electron





LED vs OLED in VLC

LED

Lower luminous efficiency

Larger modulation bandwidth

OLED

Better luminous efficiency, good brightness within eye safety level

Narrow modulation bandwidth, small driving range

Beam Pattern of OLED