Footprint Model in a Navigation System Based on Visible Light Communication

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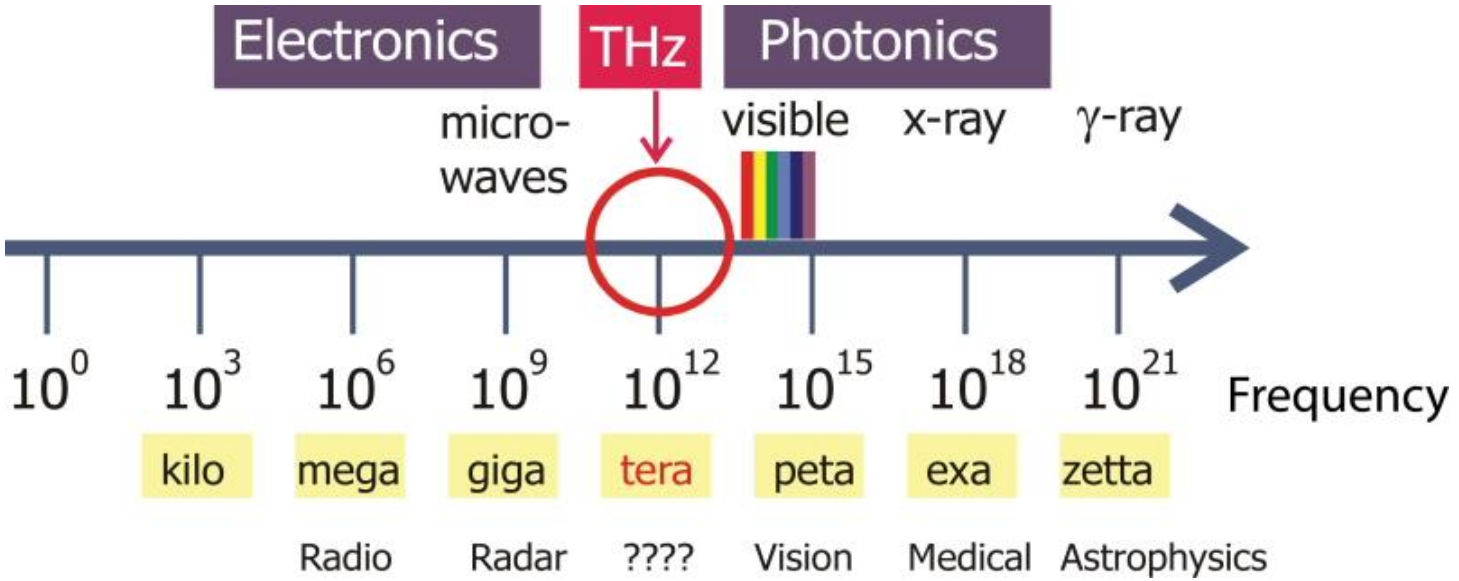
PAULA LOURO

OUTLINE

- ✓ **INTRODUCTION**
  - VLC – Transmission of data using light
  - Design of the VLC system
- ✓ **OPTOELECTRONIC CHARACTERISATION**
  - Optical sources
  - Photodetector
- ✓ **RESULTS AND DISCUSSION**
  - Test conditions
  - Decoding algorithm
- ✓ **CONCLUSIONS/FUTURE WORK**

MOTIVATION: Indoor location and data transmission using VLC

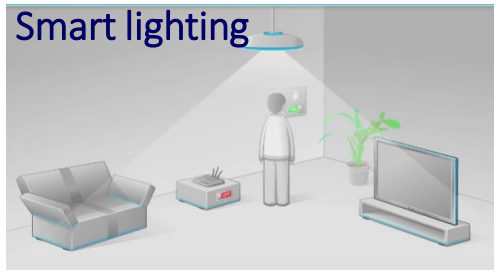
VLC – Visible Light Communication

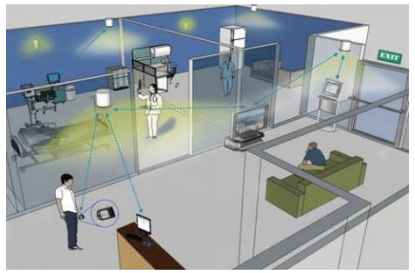


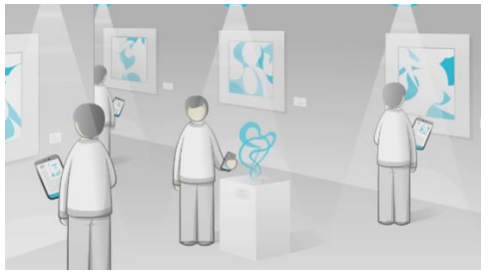
- increased bandwidth
- free and non-regulated spectrum
- line of sight technology (1 – 100 m)
- negligible power
- inexpensive (use of already existing lighting infra-structures)

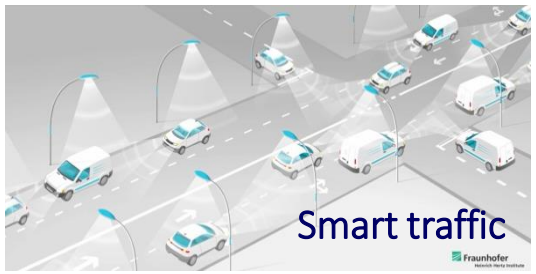
MAIN APPLICATIONS of VLC

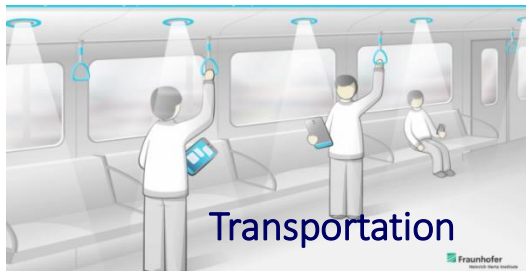
3 Gbps

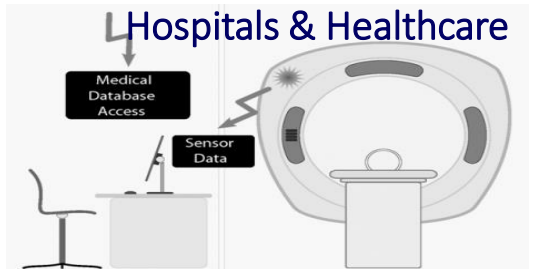


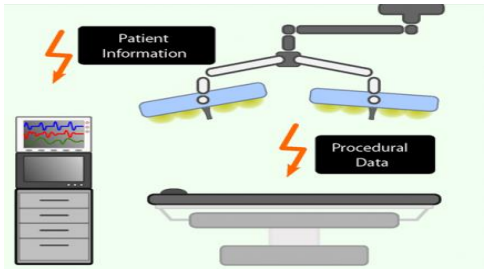


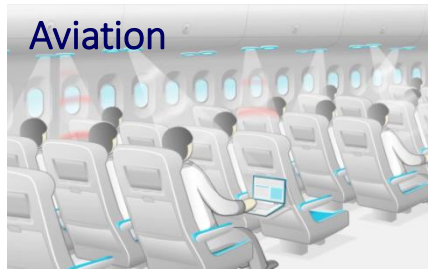












Hazardous environments :

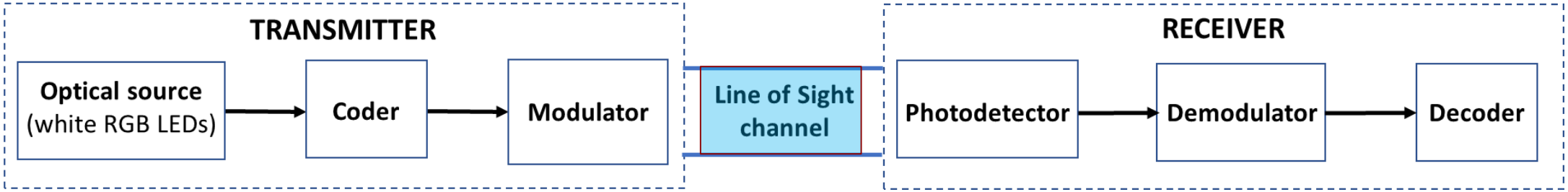
mines, petro-chemical plants, oil rigs, …

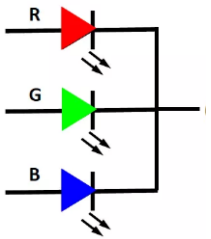
Defence & Security

WiFi spectrum relief

Location based services

VLC ARCHITECTURE



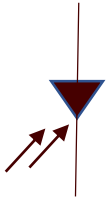


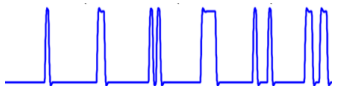
10101001

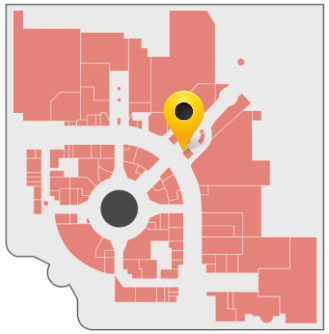
11011101

10011001

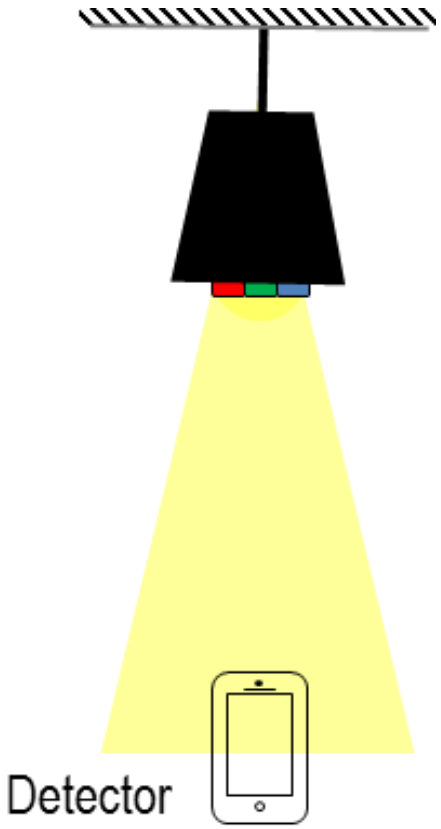
OOK

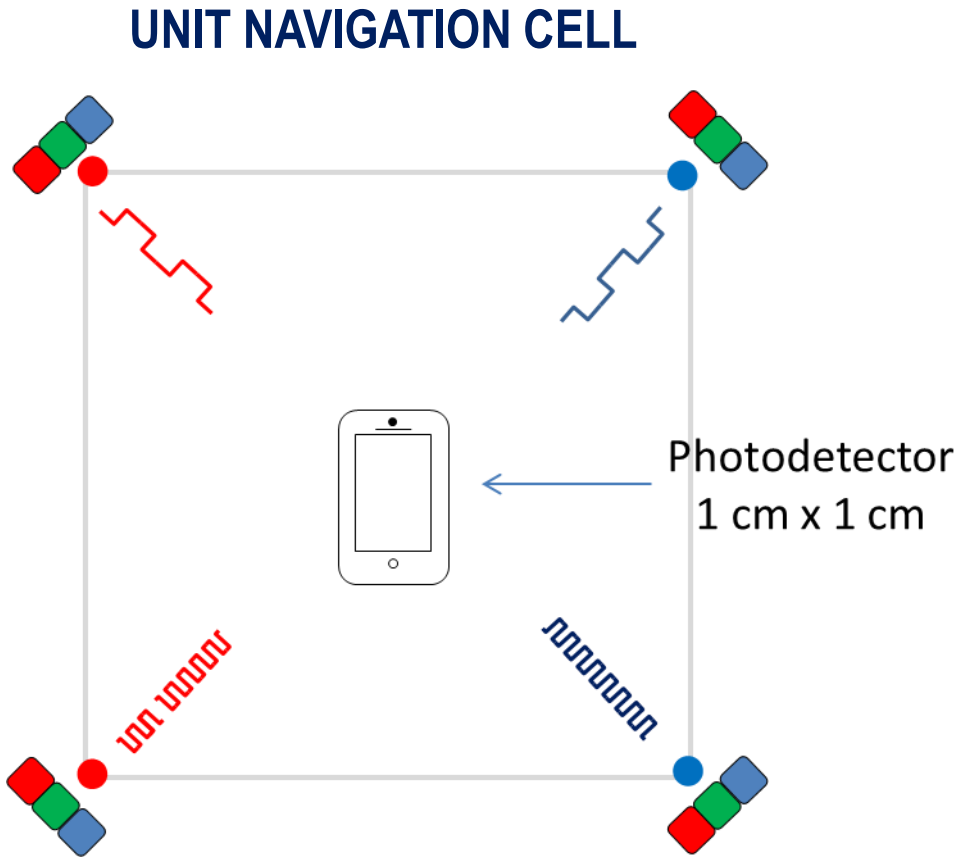




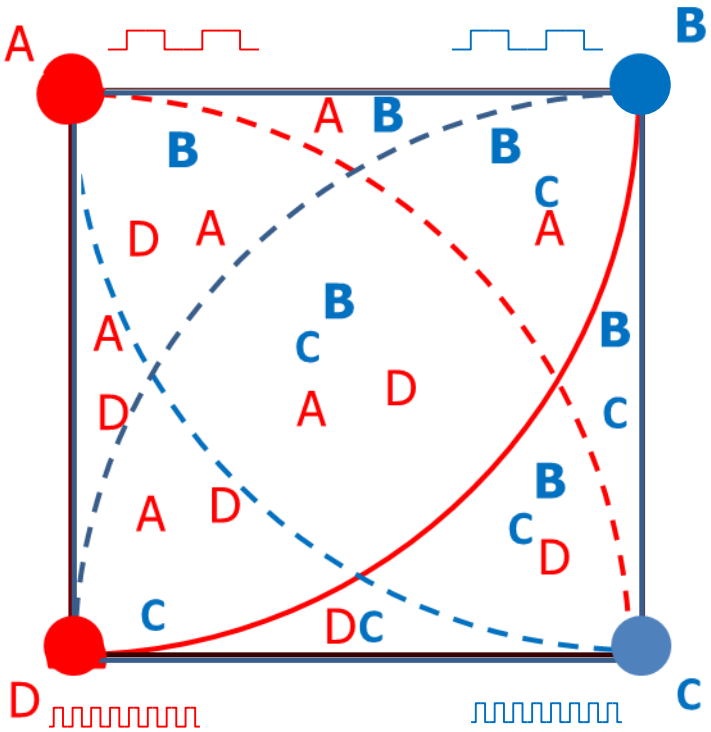


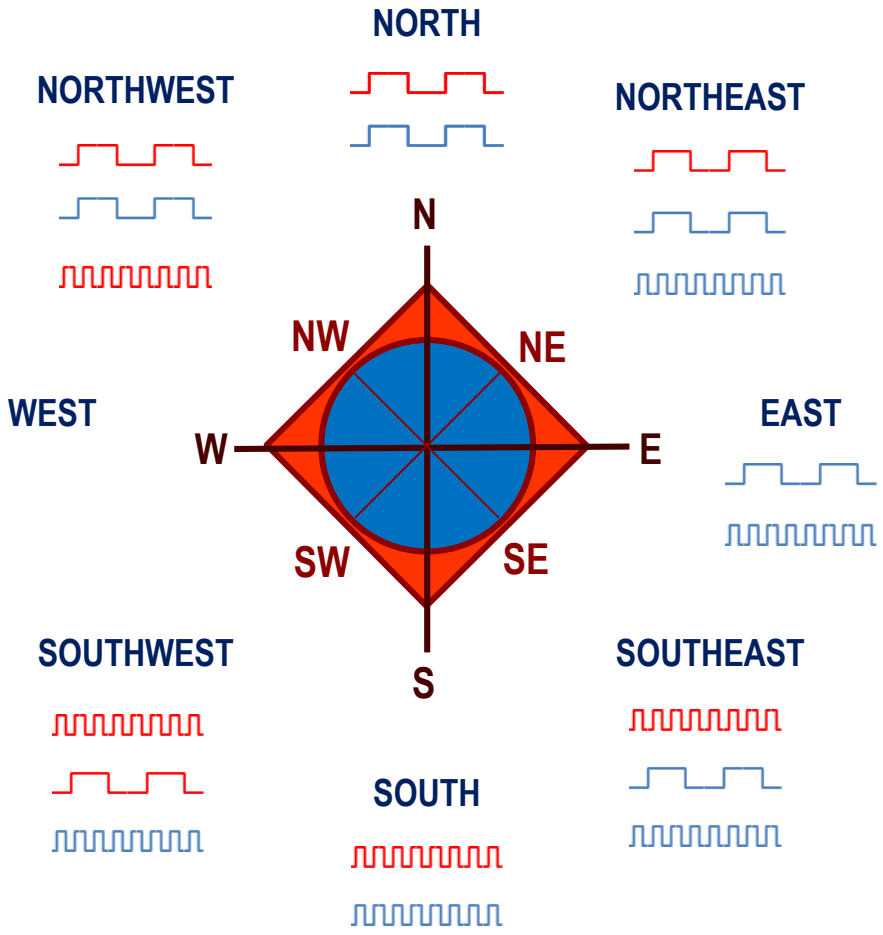
UNIT NAVIGATION CELL





LEDS EMISSION LIGHTING PATTERN



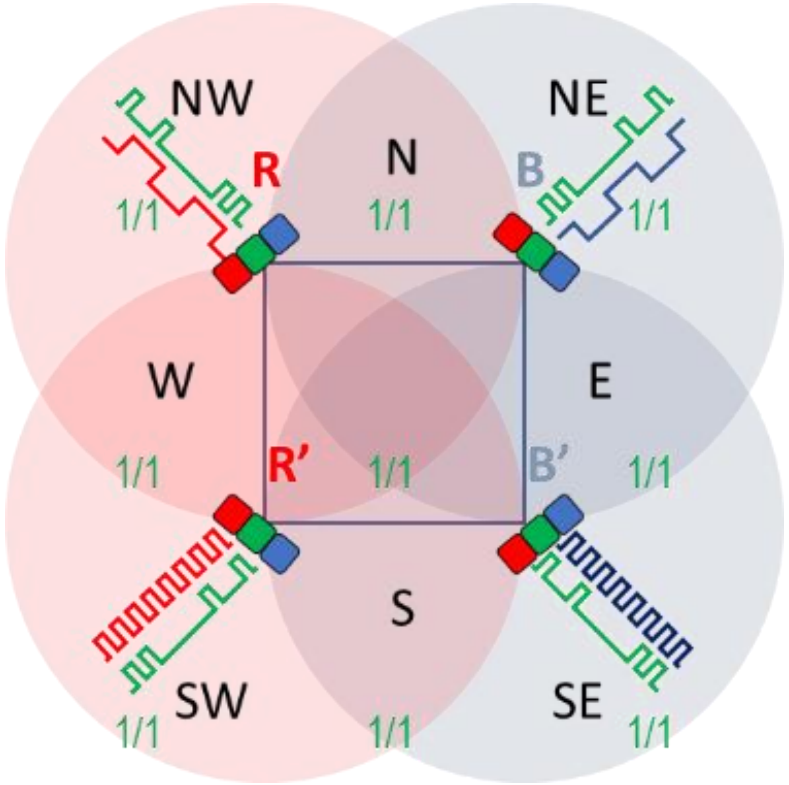


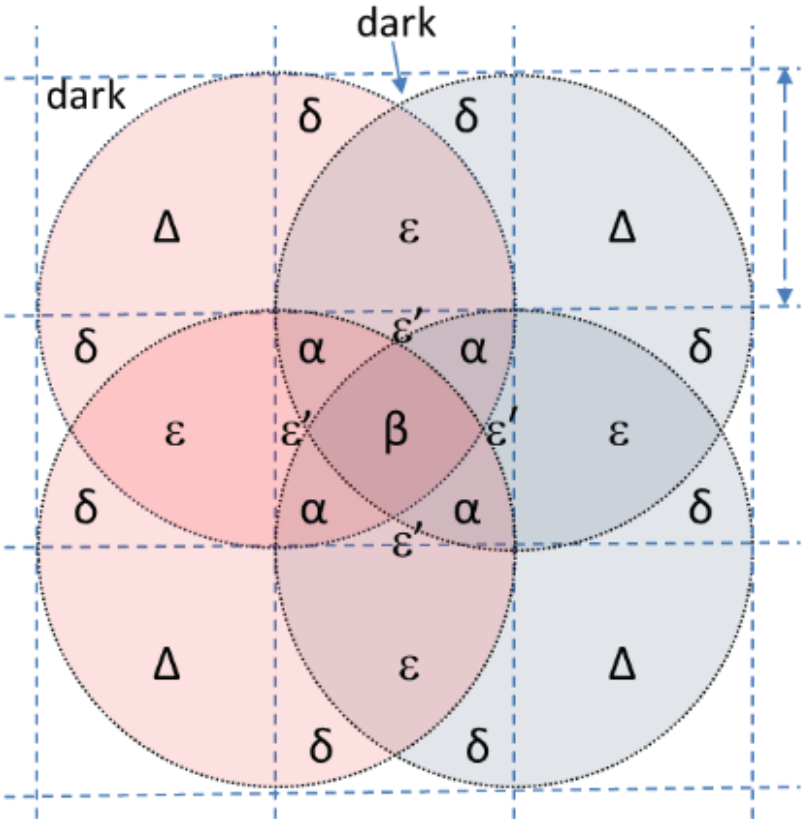
Sides(N; W; E; S): 2 signals

Corners (NW; SW; NE; SE): 3 signals

Center : 4 signals

FOOTPRINT DEFINITION





$$A_\varepsilon = 2 \times \int_0^{\pi/3} r^2 \sin^2\theta \cdot d\theta \quad (3)$$

$$A_\beta = 4\left(\int_{\pi/6}^{\pi/3} r^2 sin^2\theta \cdot d\theta + r^2\left(1 - \frac{\sqrt{3}}{2}\right)\right) \quad (4)$$

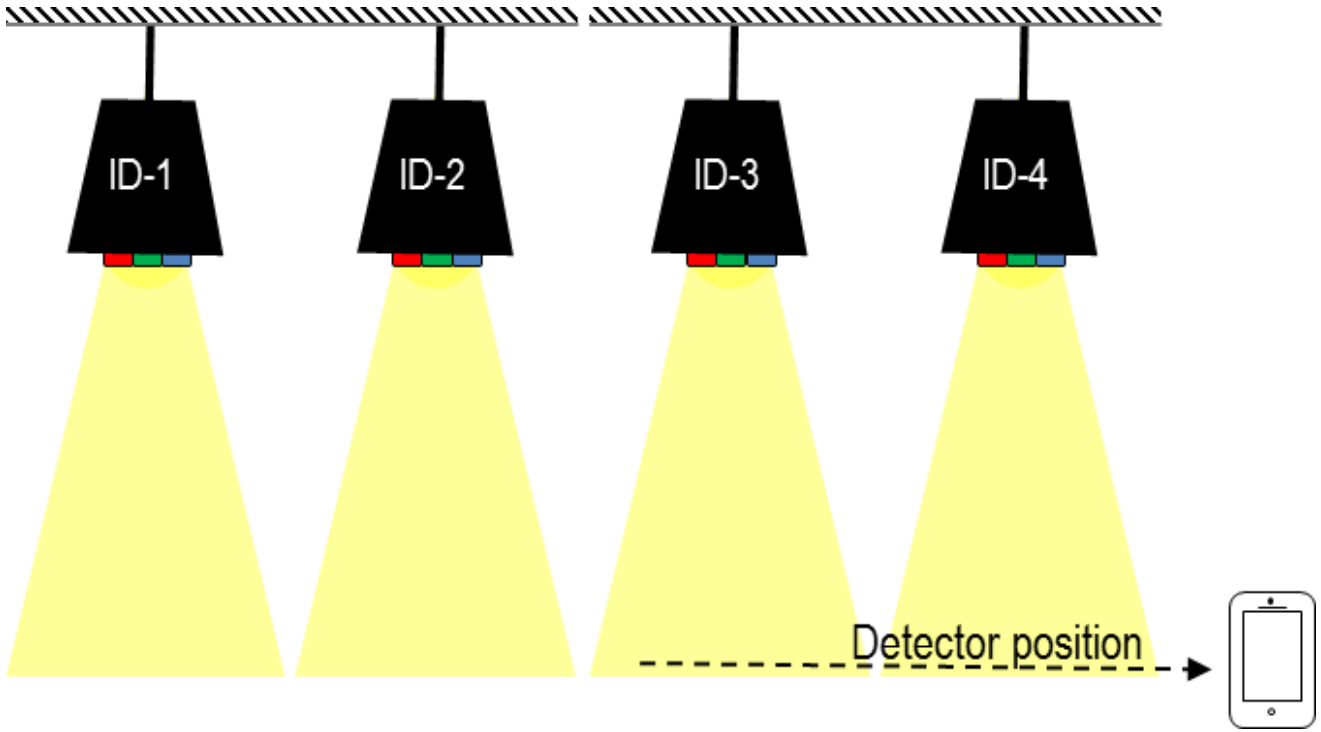
$$A_\delta = \frac{\pi r^2}{4} - A_\varepsilon = 0.171213 \cdot r^2$$

$$A_{\varepsilon'} = r^2 - A_\varepsilon - 2 \cdot A_\delta = 0.043389 \cdot r^2$$

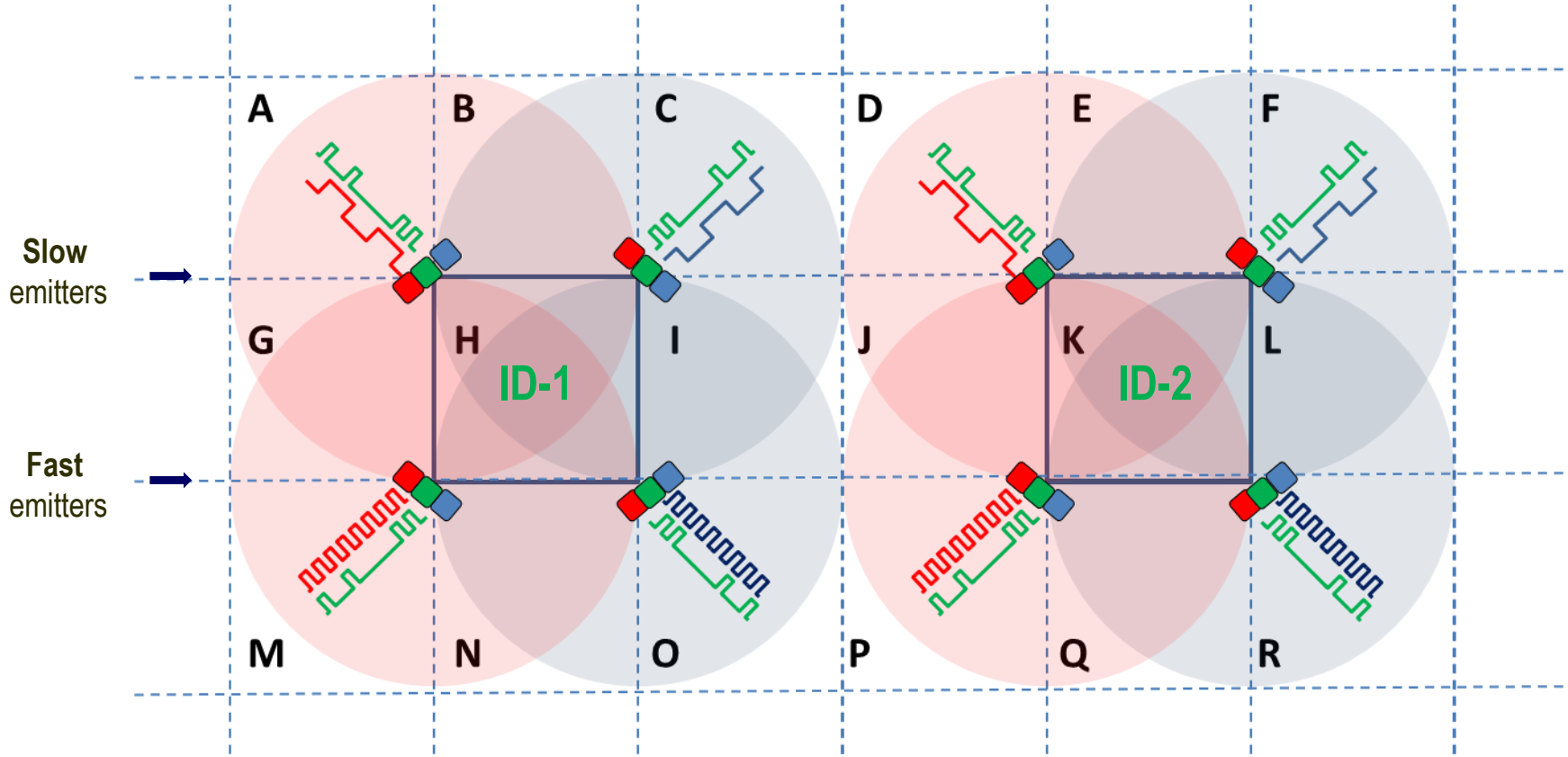
$$A_\alpha = \frac{1}{4}\left(r^2 - A_\beta - 4 \times A_{\varepsilon'}\right) = 0.337418 r^2$$

Spatial region	Area	Number of regions	Normalized area (navigation unit cell)
ε	0,614·r²	4	0,273
δ	0,171·r²	8	0,152
ε’	0,043·r²	4	0,019
β	0,511·r²	1	0,057
α	0,079·r²	4	0,035
Δ	0,785·r²	4	0,349
Δ+ δ	0,957·r²	4	0,501
ε + ε’	0,658·r²	4	0,292
Dark	0,215·r²	4	0,095

RGB WHITE LED LAMPS



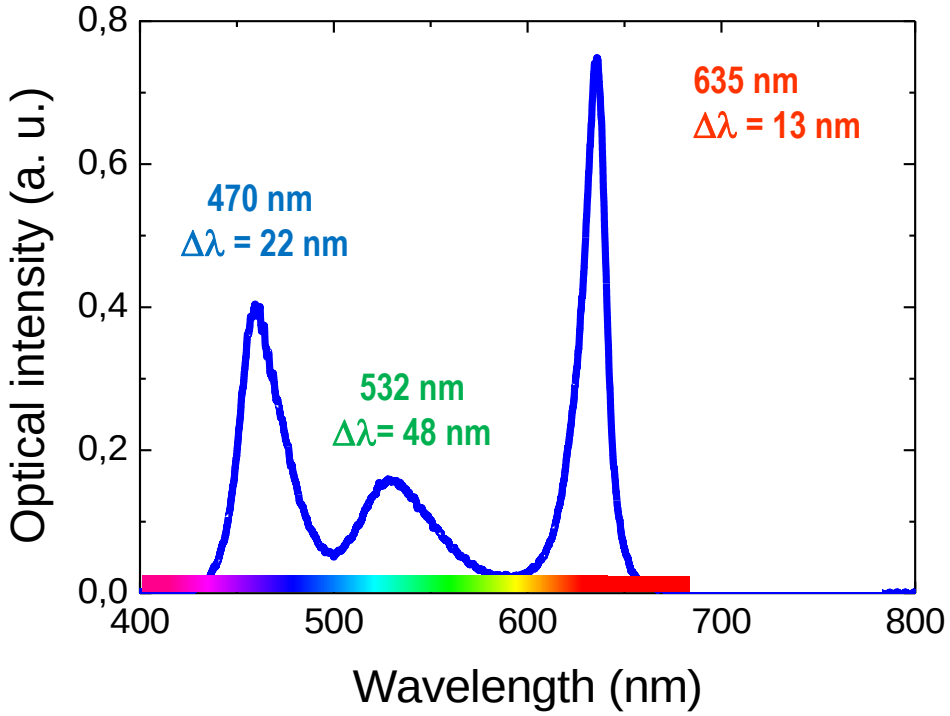
NAVIGATION CELLS



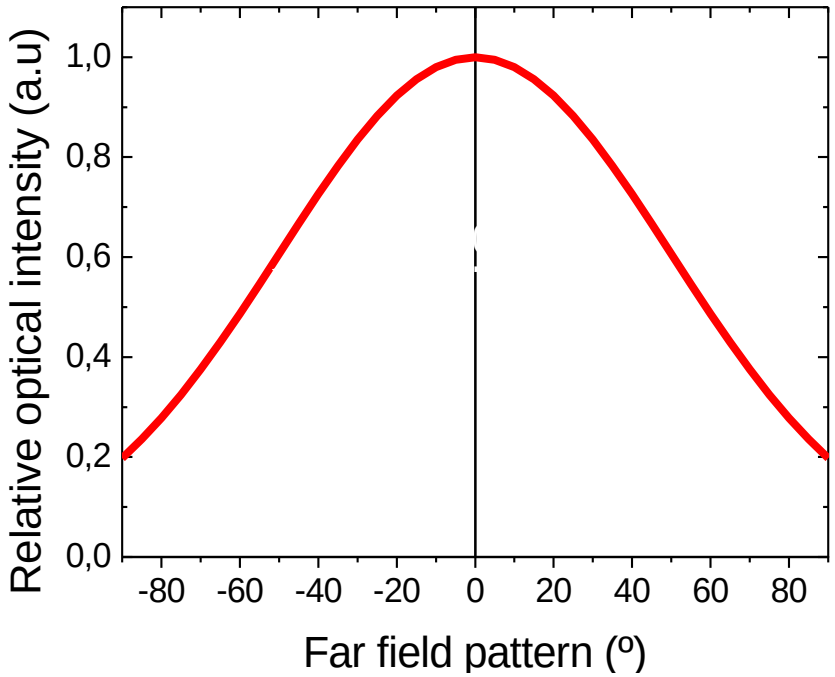
- Each navigation cell is assigned a dfiferent ID transmitted by the green emitter
- Red and blue emitters are modulated at different frequencies

WHITE LEDs

SPECTRAL OUTPUT

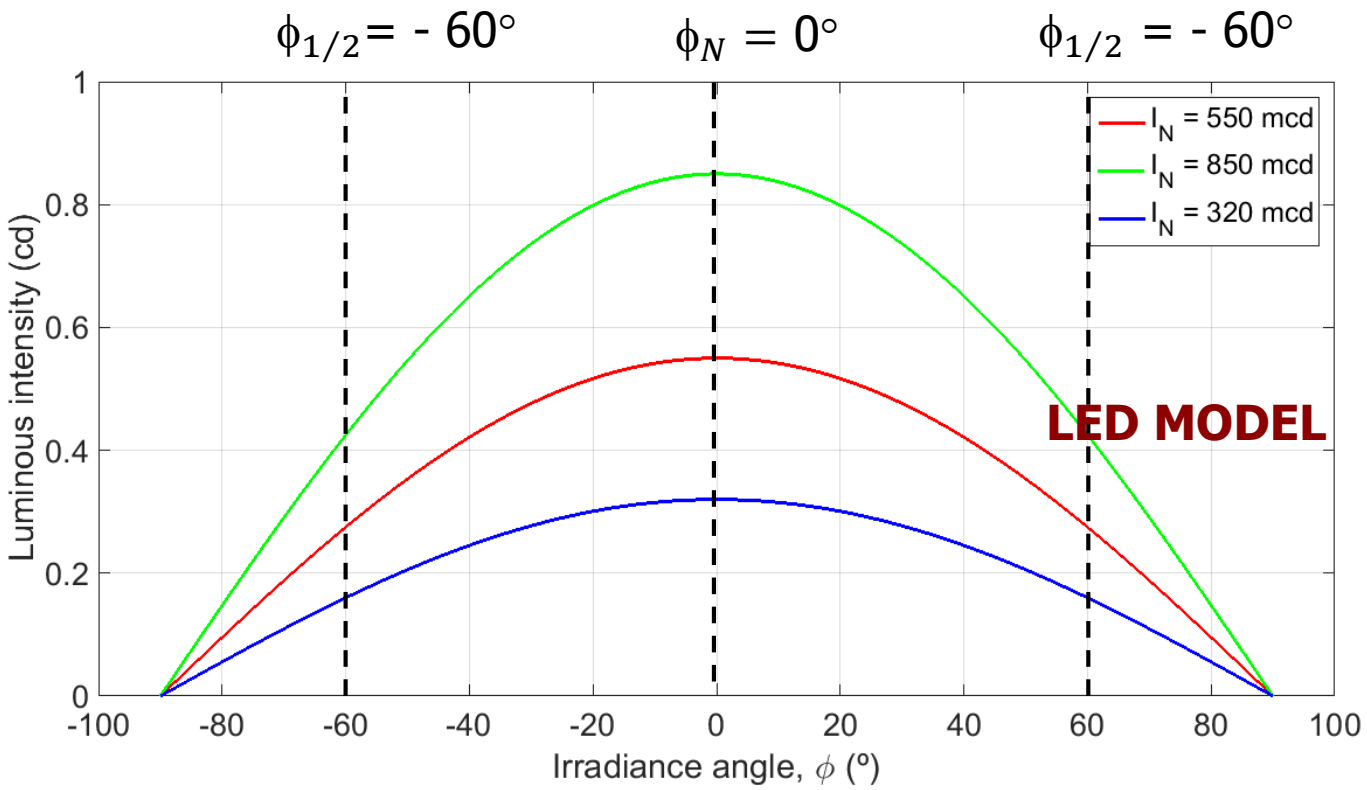


FAR FIELD PATTERN



- The magnitude and width of each RGB peaks are optimized for the white.
- The green component is lowest because the human eye has a maximum sensitivity at 530 nm.
- Wide viewing angle ≅ 60º

LED MODEL



LAMBERTIAN DISTRIBUTION

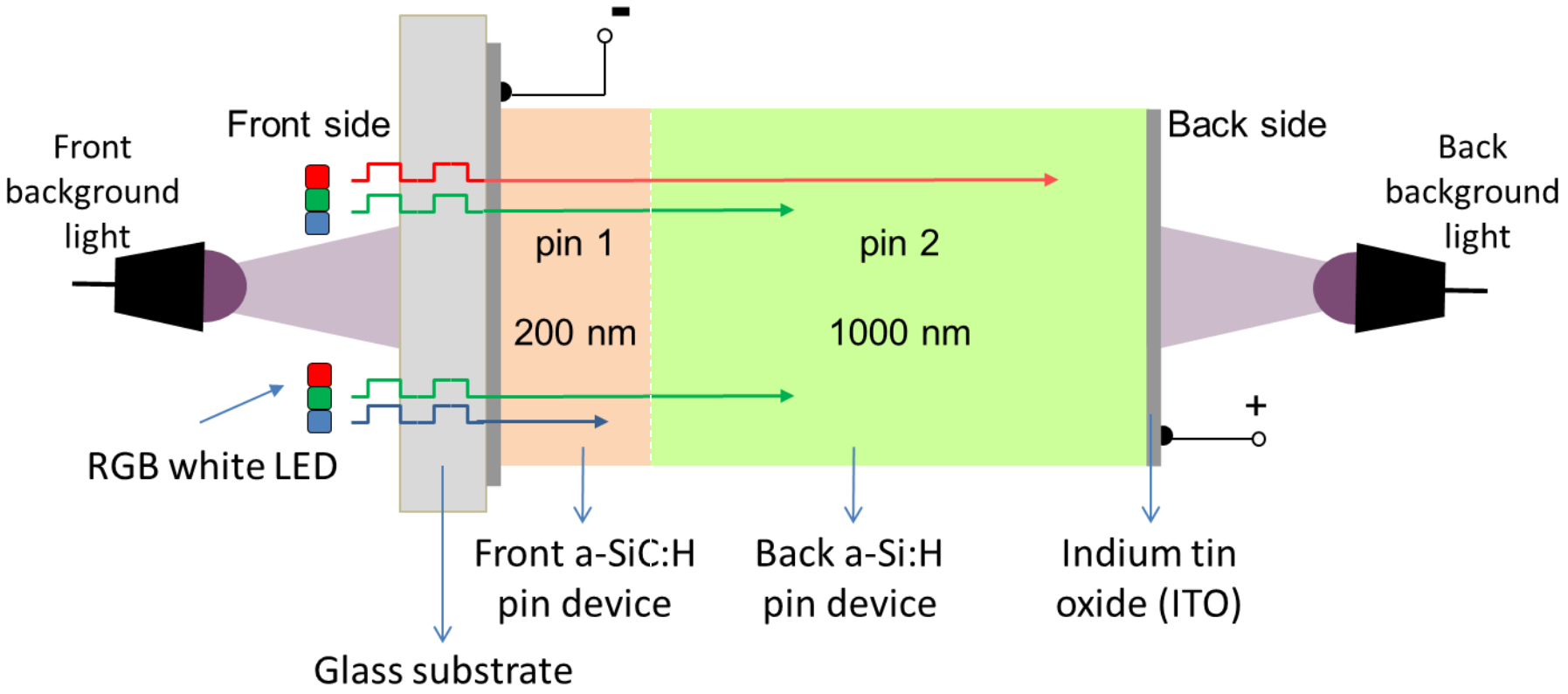
$$I(\phi) = I_N \cos^m(\phi)$$

$$m = -\frac{\ln(2)}{\ln(\cos(\phi_{1/2}))}$$

$\phi_{1/2}$= ± 60° → m = 1

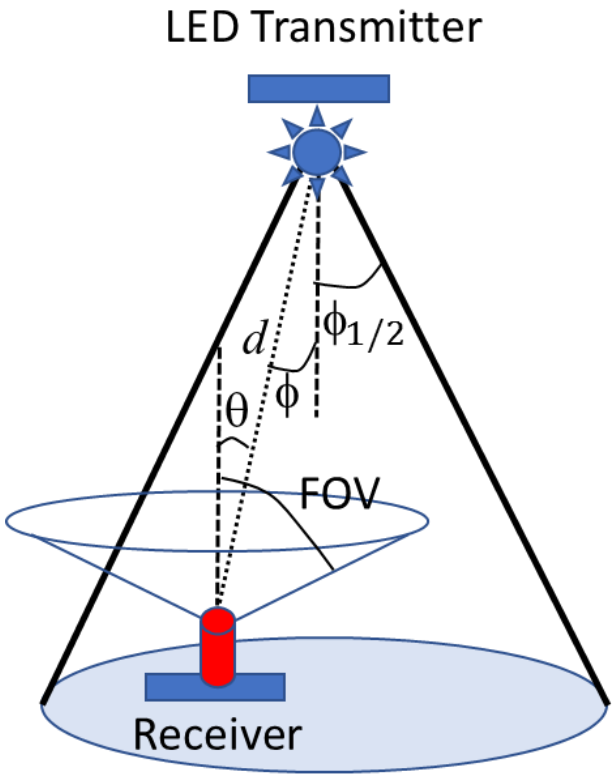
- The luminous intensity varies with the direction
- Exhibits a maximum at the axial direction (0°) and half of the maximum at $\phi_{1/2}$= ± 60°

PHOTODETECTOR



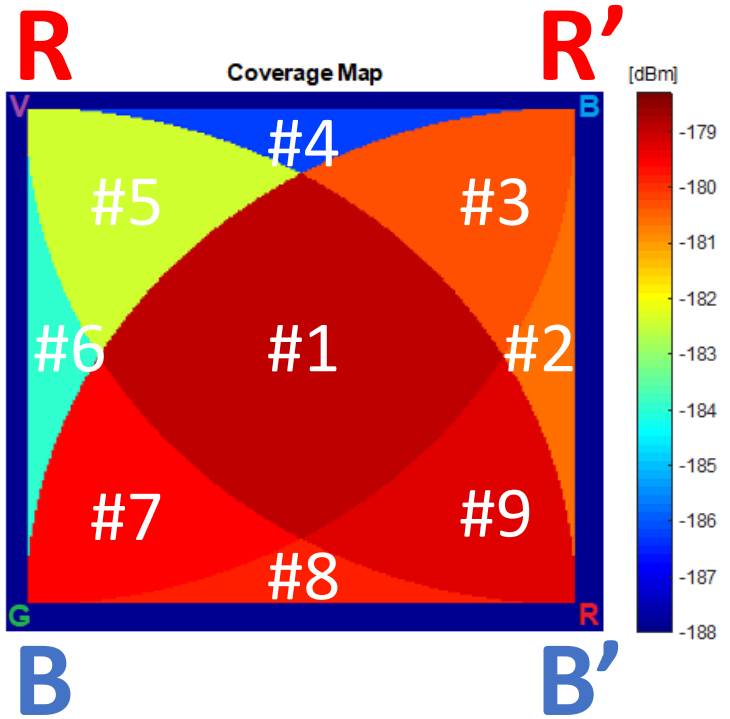
- High blue absorption
- High red transmittance
- Full green absorption
- High red absorption

FOOTPRINT



Channel gain

$$G = \frac{(m+1)A}{2\pi D_{t-r}^2} I_N \cos^m(\phi) \cos(\theta)$$

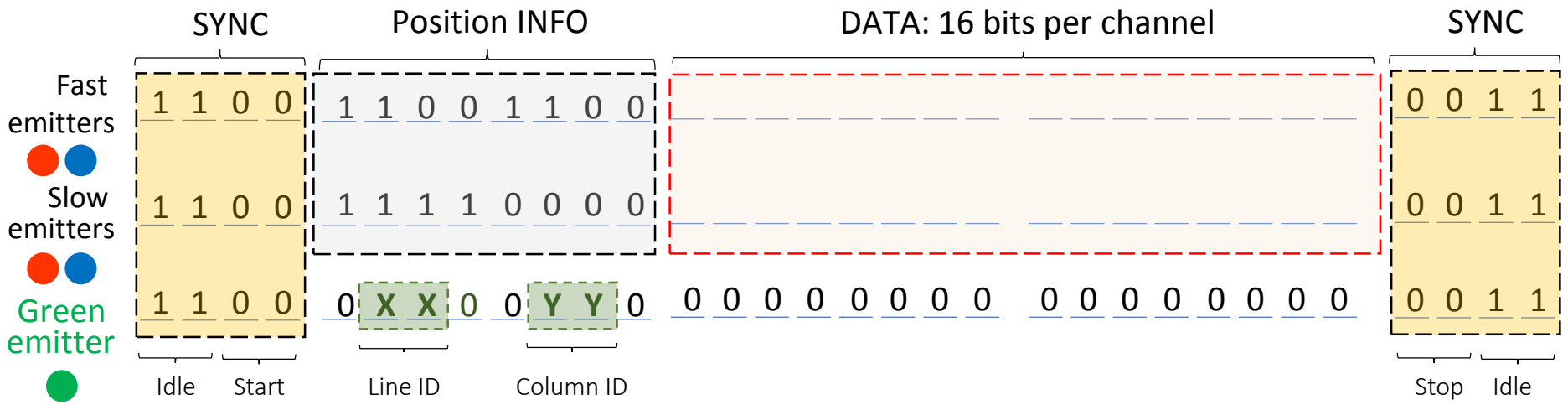


#1 – R+R'+B+B'
#2 – R'+B'
#3 – R+R'+B'
#4 – R+R'
#5 – R+R'+B
#6 – R+B
#7 – R+B+B'
#8 – B+B'
#9 – R'+B+B'

CODER & MODULATION

Bit stream: 32 bits word

SYNC (Start) + Position INFO + MESSAGE + SYNC (End)



OOK – On-Off Keying modulation

LEDs are turned ON and OFF according to the bits in the stream

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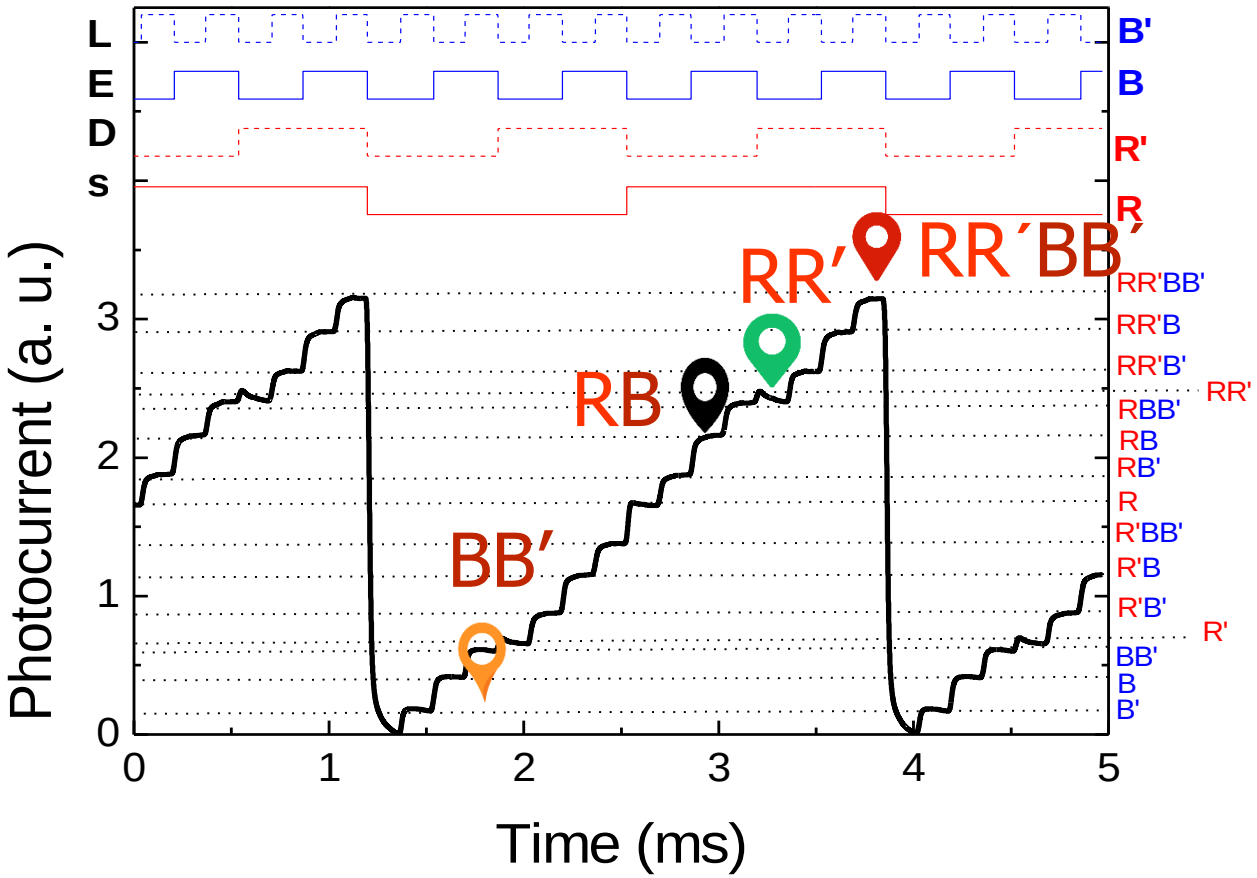
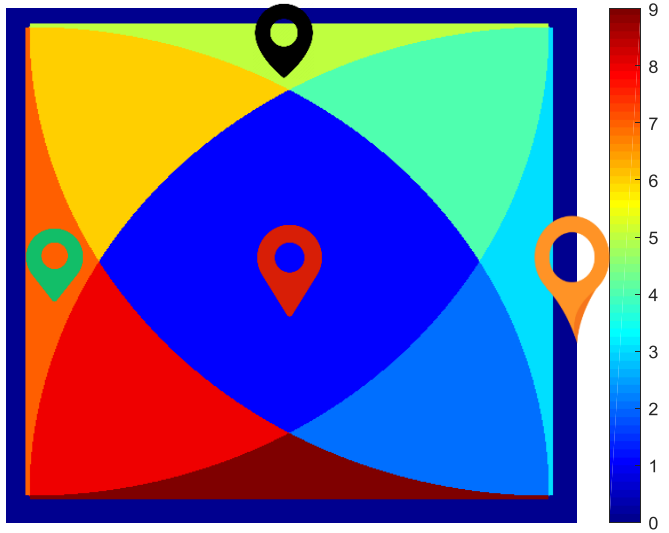
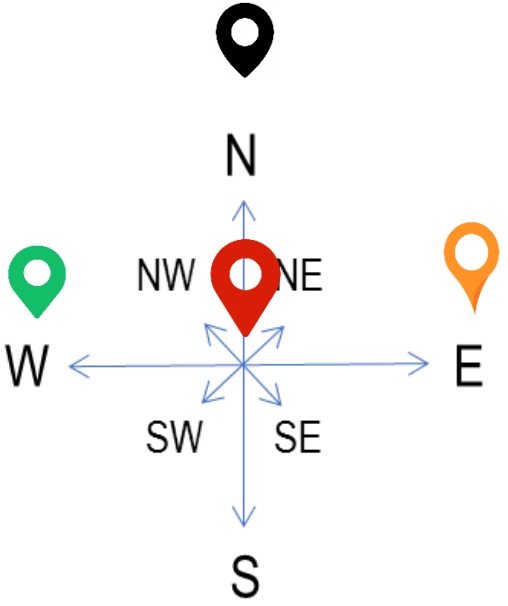
DECODING STRATEGY

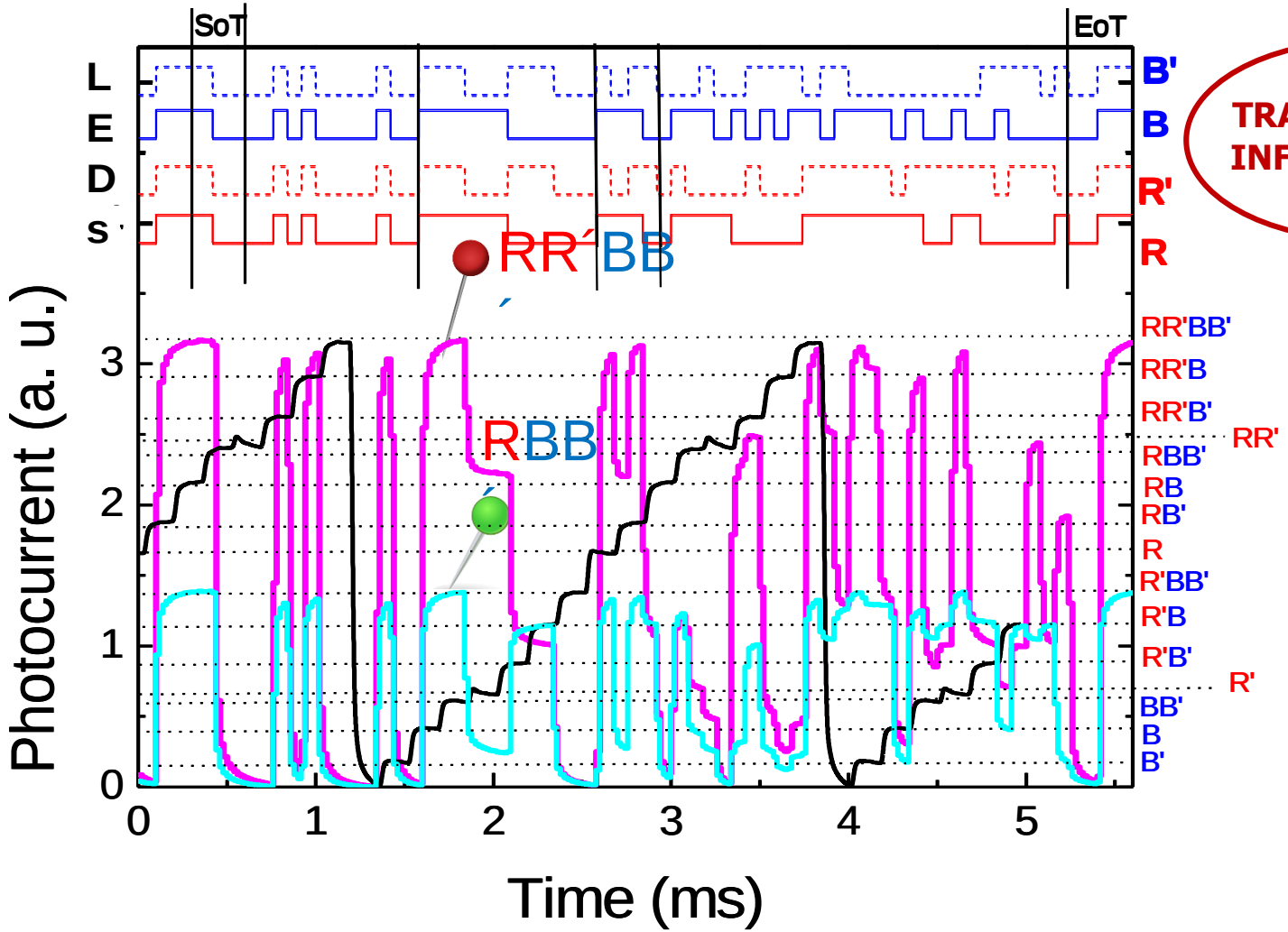




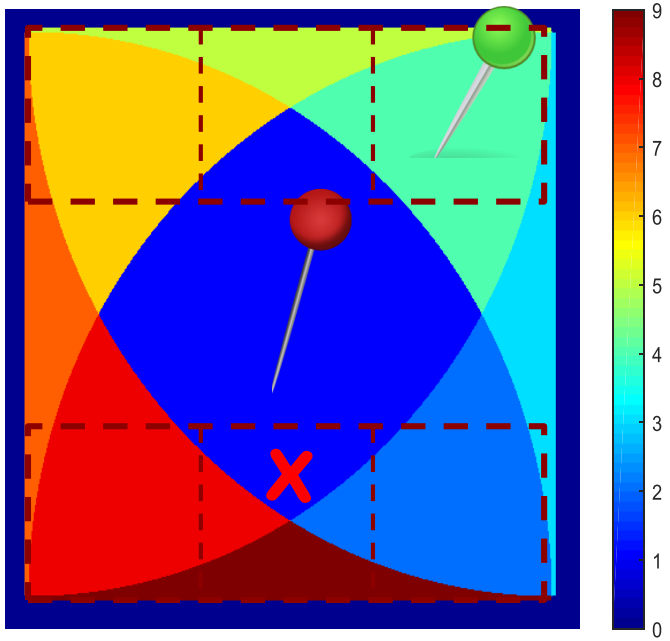


- Simultaneous modulation of **4** emitters
- The resultant optical signal is a combination of 4, 3, 2 or 1 optical signals → **16** possible photocurrent levels
  - (The driving current of each LED emitter was adjusted to provide different levels of photo excitation)

MUX SIGNAL



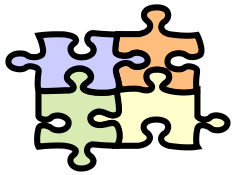
TRANSMITTED INFORMATION



CONCLUSIONS

- Simulation of the propagation model in LoS conditions
- Definition of the coverage areas and footprints
- Use of 64 bits word
- Syncronization of frames
- Calibration data
- Footprints – photocurrent signal

FUTURE WORK



- BER analysis
- NonLoS conditions
- Model calibration