# Poster: Retroreflective MIMO Communication

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## MOTIVATION

Retroreflective communication has the intrinsic advantage of ultra low power and flexible pointing requirement, and thus is suitable for IoT [1] and V2X [2] applications. While LCD is commonly used as optical modulator due to the low cost, its slow response time becomes the performance bottleneck, when it is used in the SISO setting. Therefore, it is desirable to develop MIMO techniques.

## DESIGN

We propose to design retroreflective MIMO channel based on polarization division multiplexing (PDM), with multiple LCD modulators and photodiode (PD) receivers. LCD shutter works as a bi-state modulator which rotates the polarized light by 0 ° or 90 °. With polarizer on each side of LCD, it could retroreflect incoming light or absorb it. The retroreflected light is polarized to the angle of front polarizer, which is imperceptible by human eyes but could be separated using polarizer on PD receivers.

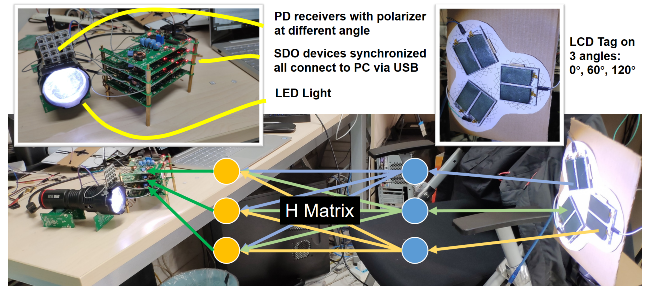
Given $M$ individual LCDs and $N$ PD receivers (Fig. 1a), the received signal $R_n$ could be expressed using channel matrix $H_{nm}$, retroreflected signal strength $T_m$ and their angles $\theta_{t_i}$, also background noise signal $R_{0n}$.

$$R_n = R_{0n} + H_{nm}T_m, \quad H_{nm} = \cos^2(\theta_{r_n} - \theta_{t_m})$$

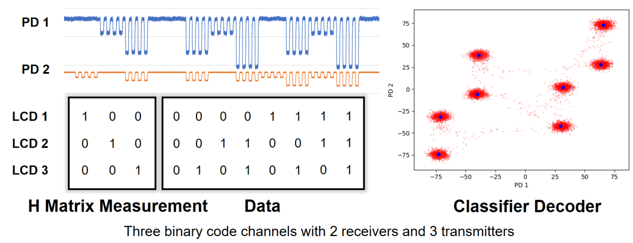
Note that the maximum rank of $H_{nm}$ is 3 when $M \geq 3$ and $N \geq 3$, which means even if we have arbitrary amount of transmitters and receivers, there are only 3 independent communication channels in this system [3], which means the PDM is limited in up to 3 times throughput gain.

Our key insight is that LCD as a bi-state modulator cannot always utilize bandwidth efficiently since it cannot generate arbitrary level of signal strength. This leads to our idea of generating more channels even if they are not independent.

The receiving signal constructs a M-dimensional space, while $N$ LCDs have only $2^N$ symbols. If all the $2^N$ symbols could be recognized, we could say that we get $N$ binary code channels, which improves the throughput by $N$ times. Note that this scheme works even if $M$ is less than $N$, which could be seen in the example Fig. 1b.




**(a) Experimental Setup**




**(b) Raw Waveform**

**Figure 1: Preliminary Results**

Exceeding the limit of independent channel requires elaborate design of polarization angles, thus it is limited to single user MIMO. With an extra LCD in front of the tag, it can perform channel selection when two angles are too close to decode signals, by rotating the polarized light by 0 ° or 90 °.

## PRELIMINARY RESULTS

We built a prototype system to evaluate our design. Reader send carrier signal on LED light and receive retroflected signal. The optical part includes an array of PDs and amplifiers, while multiple output is connected to readers.

Our preliminary results show that we could successfully decode three channels using only 2 receivers, with a classifier decoder.

## REFERENCES

[1] Xieyang Xu, Yang Shen, Junrui Yang, Chenren Xu, Guobin Shen, Guojun Chen, and Yunzhe Ni. Passivevlc: Enabling practical visible light backscatter communication for battery-free iot applications. In *ACM MobiCom*, 2017.

[2] Guojun Chen, Purui Wang, Lilei Feng, Yue Wu, Xieyang Xu, Yang Shen, and Chenren Xu. Long range retroreflective v2x communication with polarization-based differential reception. In *ACM SenSys*, 2018.

[3] Darko Ivanovich, Samuel B Powell, Viktor Gruev, and Roger D Chamberlain. Polarization division multiplexing for optical data communications. In *SPIE Optical Interconnects XVIII*, 2018.



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