MIMO-Visible Light Communication Design (VL2-11)

Student: Xiaoli Wang  Supervisor: Prof. Vincent Lau

Introduction
Multiple input and output visible light communication system (MIMO-VLC) is a topic worth studying because VLC has the potential of simultaneous illumination and communications, and MIMO can help to increase the capacity. However, LED nonlinearity induced distortion is a major challenge in this topic that needs to be solved.

Objectives
- Simulate and analyze the performance of MIMO-VLC point to point communication systems in indoor environment.
- Identify technical challenges in MIMO-VLC systems.
- Provide solutions to one of the technical challenges—distortions caused by the effect of LED nonlinearity.

Methodology

MIMO-VLC using Spatial Modulation

Transmitters: 4 LED arrays; Receivers: 3 x 3 photodiode detectors.
This is a simple method to reduce the requirement of alignment between transmitters and receivers. Each time, 2 bits are transmitted and the 4 combinations of the 2 bits are mapped to the 4 transmitters, respectively. Thus, only one transmitter is active each time. Because of this, the system doesn’t fully utilize the idea of MIMO.

MIMO-VLC using Spatial Multiplexing

2:9 Imaging MIMO system
MIMO and OFDM are combined in this system, so multiple spatial channels are created and multiple data streams are transmitted simultaneously. Prior to the photodiode detector, we also use an imaging lens to reduce the cross-coupling between different transmitters and receivers. VLC has the limitation that only real signals can be transmitted, so OFDM signals are preprocessed to satisfy the Hermitian-symmetry requirement before IFFT operation.

Methods to reduce LED nonlinearity effect

Method 1: Bias voltage with power back-off
The green curve shows the nonlinear L-V curve of the LED. The linear region is about 200m Vpp and the quasi-linear region is about 400m Vpp. Because OFDM signals have high peak-to-average ratio (PAR), they are more vulnerable to this nonlinearity effect. In this method, a bias voltage is added to the OFDM signals. To ensure that the peak of the OFDM signals can also operate in the quasi-linear region, certain level of power back-off is required.

Method 2: Pre-distortion
We expand the quasi-linear range of the LED by changing the nonlinear green curve into the linear blue curve. This is done by processing the input voltage \( V_{in} \) and put the voltage \( V_{out} \) onto LED as the LED forward voltage. In this way, the real output current will be \( I_{op} \), which corresponds to \( V_{in} \) on the linear blue curve.

Results and Conclusion

Performance with nonlinearity effect

Method 1

Conclusion: The performance of the MIMO-VLC system will degrade with the increase of the distance between the transmitter and receiver and the increase of LED half-power semi-angles. In dealing with LED nonlinearity effect, bias voltage together with certain power back-off levels can improve the system performance, and the performance can be further improved to achieve reliable communication by pre-distortion.