ITU Kaleidoscope 2015

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A DCO-OFDM System Employing Beneficial Clipping Method

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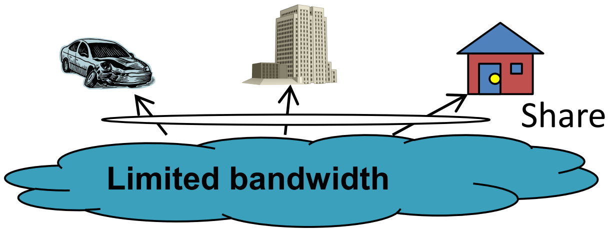
Outline

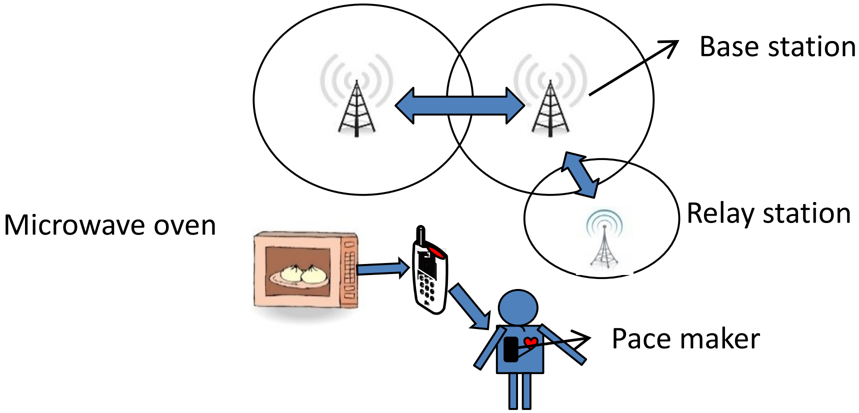
- Why optical communication
- The challenge of OFDM modulation in optical wireless system
- The proposed beneficial clipping method
- Results and conclusion

Current Status of Radio Wireless Communication

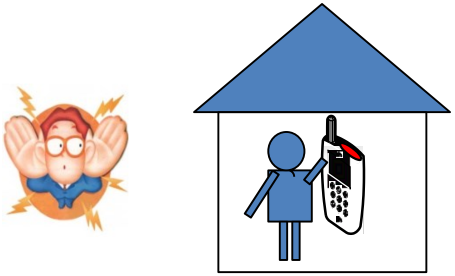
- **Limited bandwidth**



- **Interference**



- **Security**



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

RF : Radio Frequency

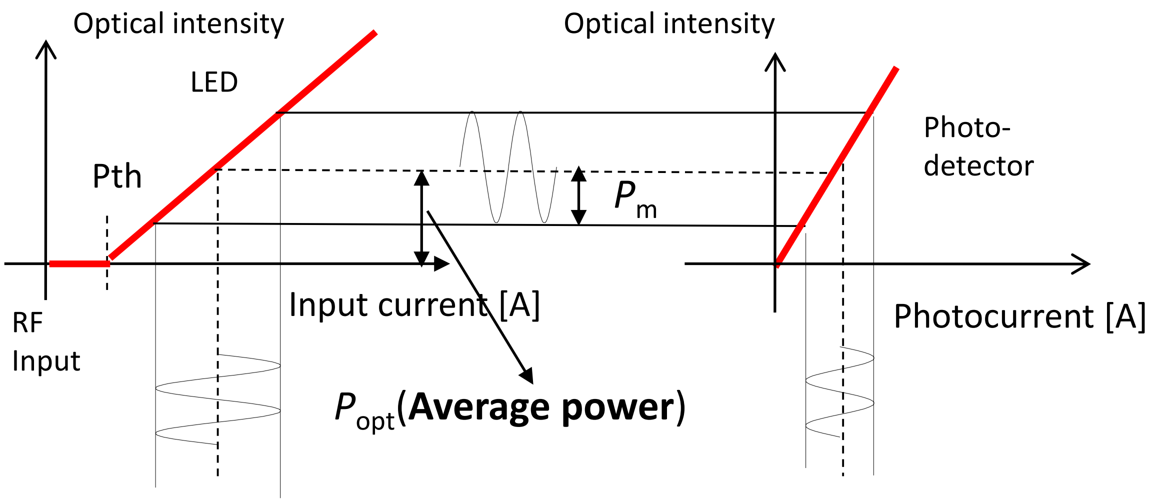
OWC : Optical Wireless Communication

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

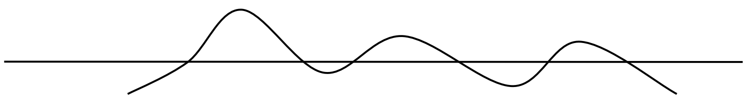
IEEE 802.15.7 Visible Light Communication

The IEEE 802.15.7 Visible Light Communication Task Group has completed a PHY and MAC standard for Visible Light Communications (VLC).

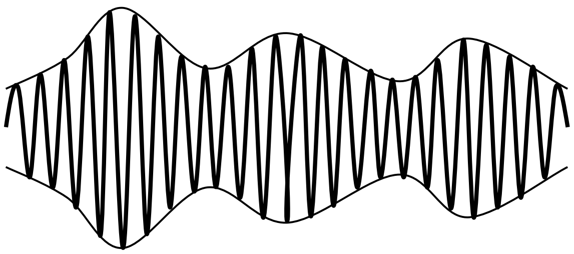
Intensity modulation and direct detection (IM/DD)



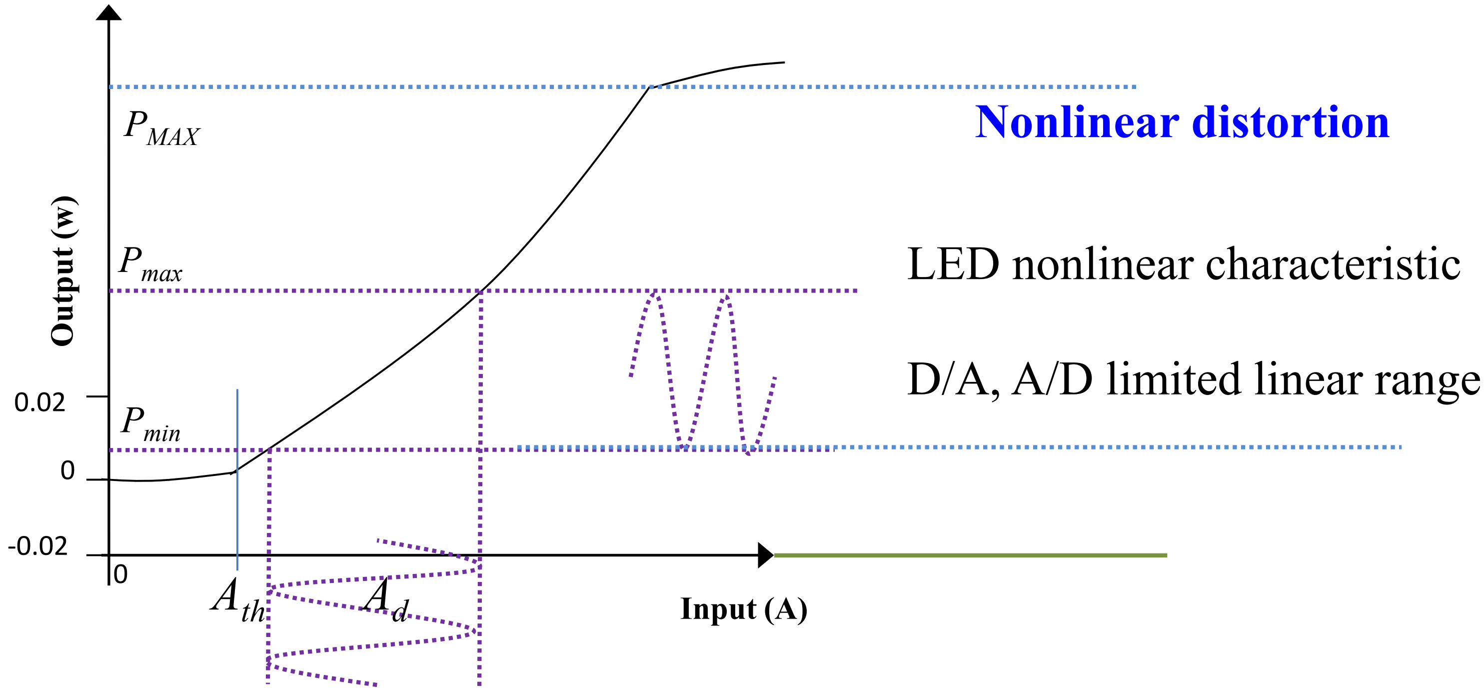
RF Sub-carrier



Intensity modulated signal



Output Character of LED

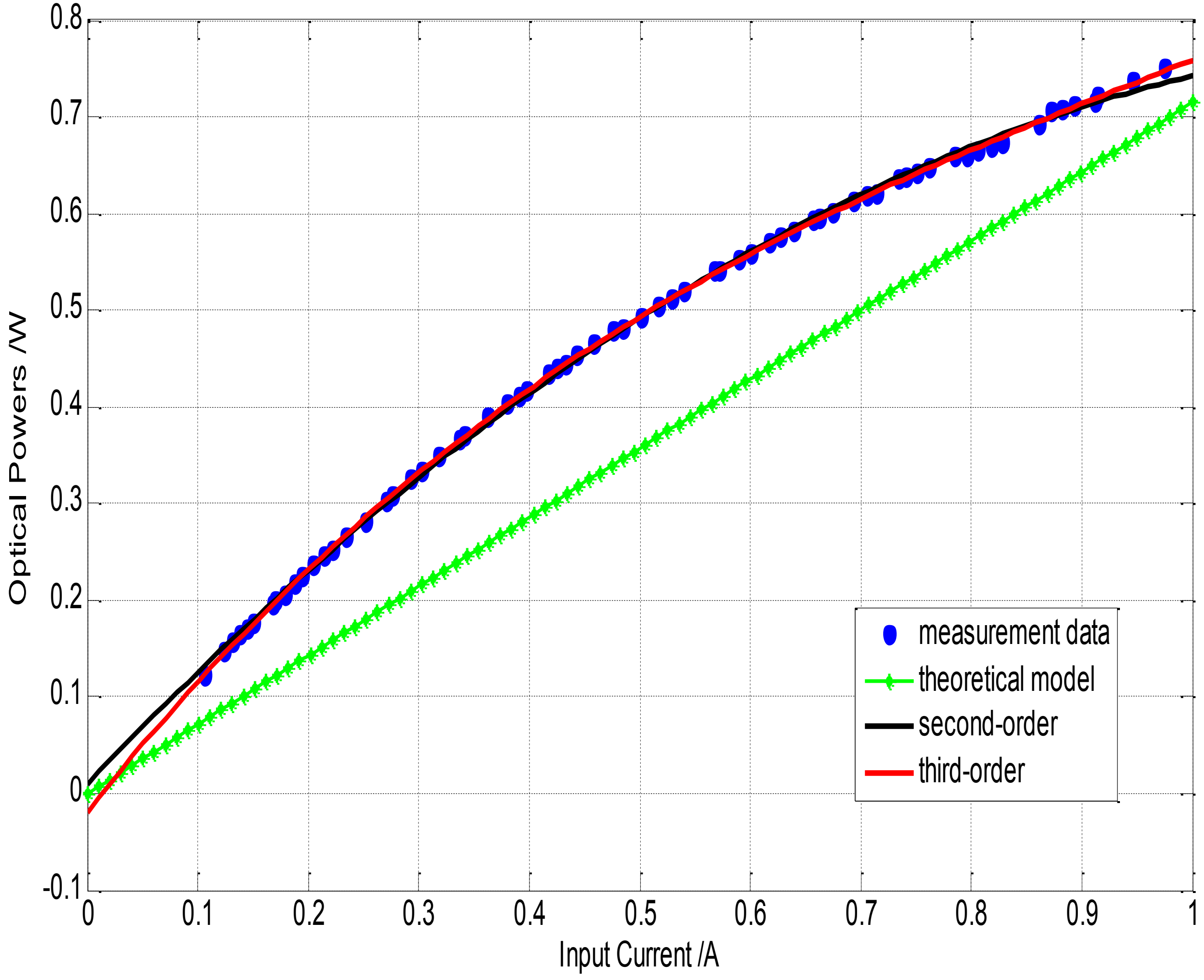


Modulation Depth *m*:

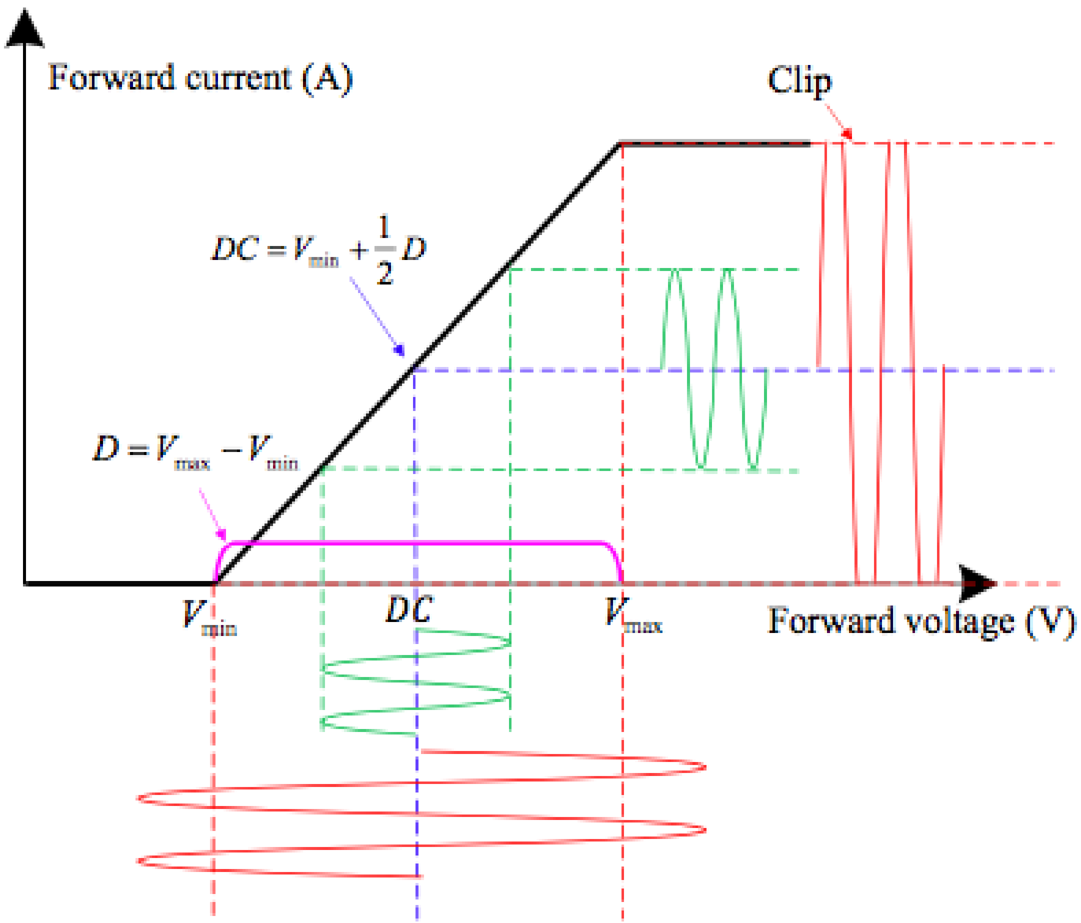
$$m = \frac{P_{\max} - P_{\min}}{P_{MAX}}$$

In optical wiirless systems, the system modulation depth is limited to a narrower range for high transmission speed.

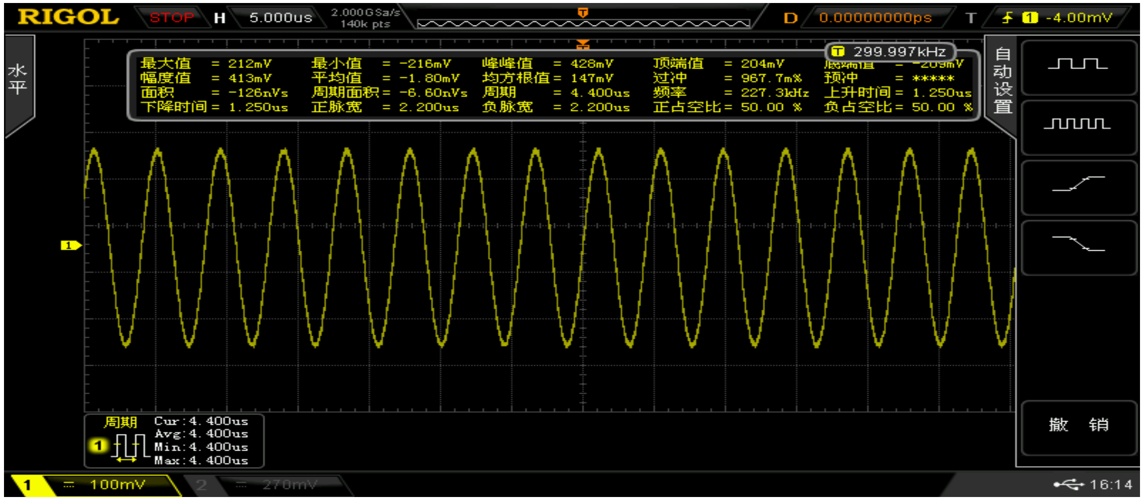
Experiment results



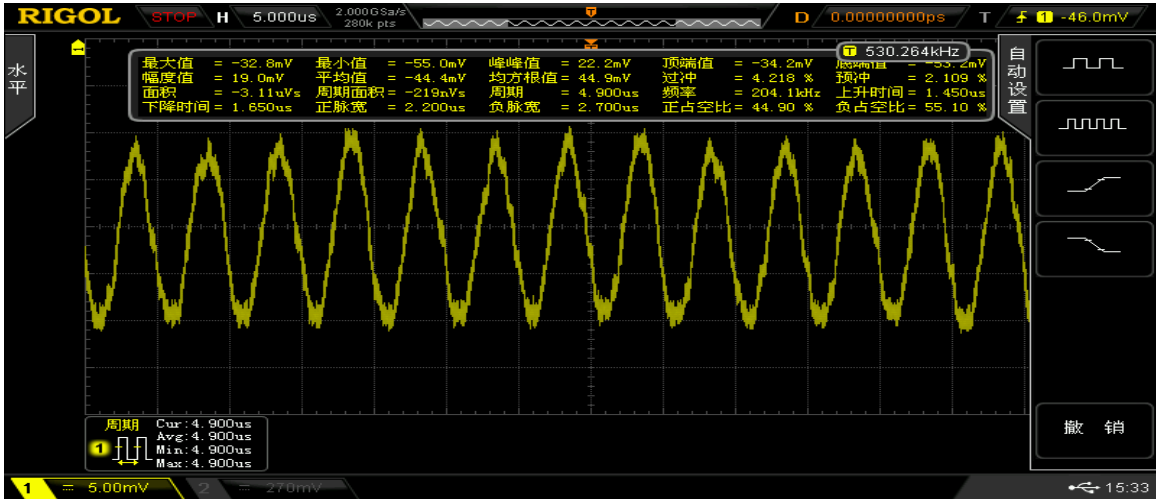
Peak Clip of LED



FM signal over optical wireless channel experiment results



Transmitted FM signals

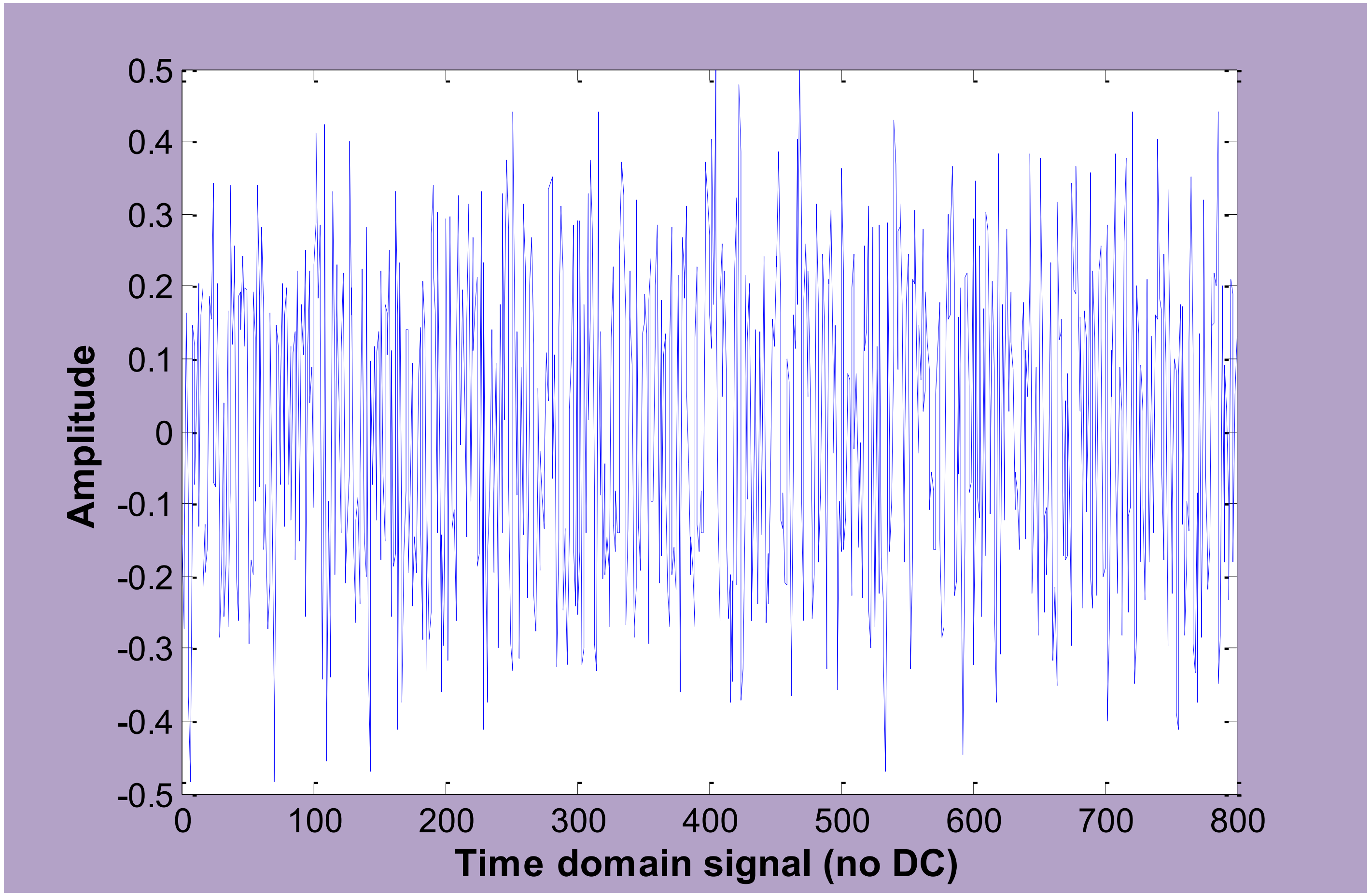


Received FM signals

OFDM signal

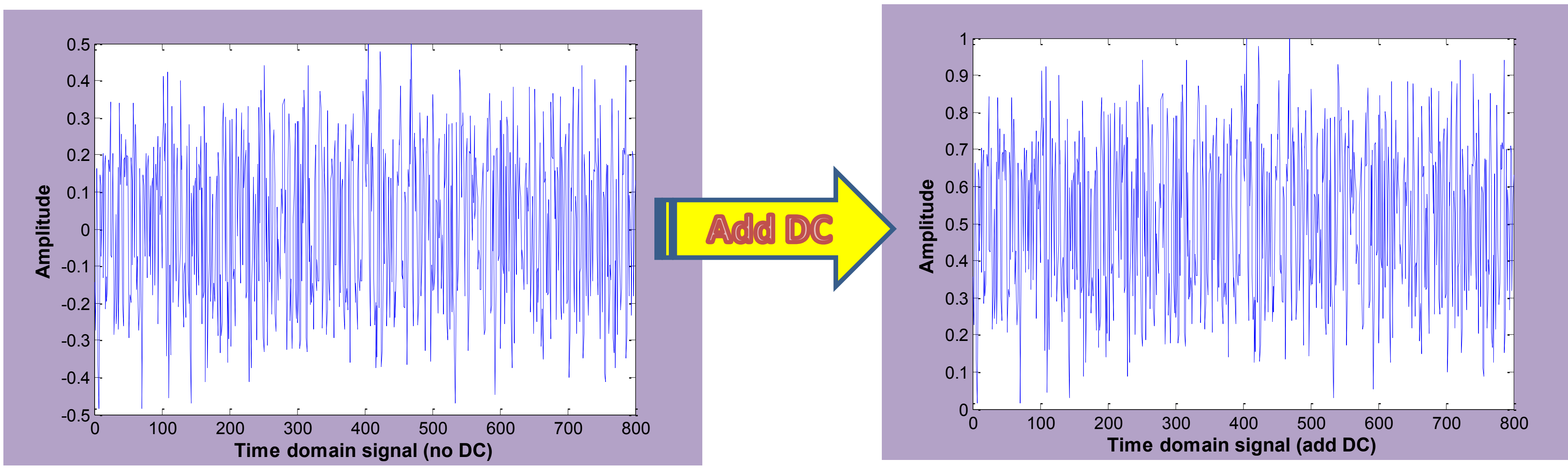
orthogonal frequency division multiplexing

High PAPR (Peak to Average Power)



OW OFDM signal

orthogonal frequency division multiplexing



Light intensity must be ***unipolar*** and ***non-negative.*** Directed circuit (DC) should be added.

Why introduce beneficial clipping to DCO-OFDM systems?

In the VLC systems, the system modulation depth is limited to a narrower range for high transmission speed.

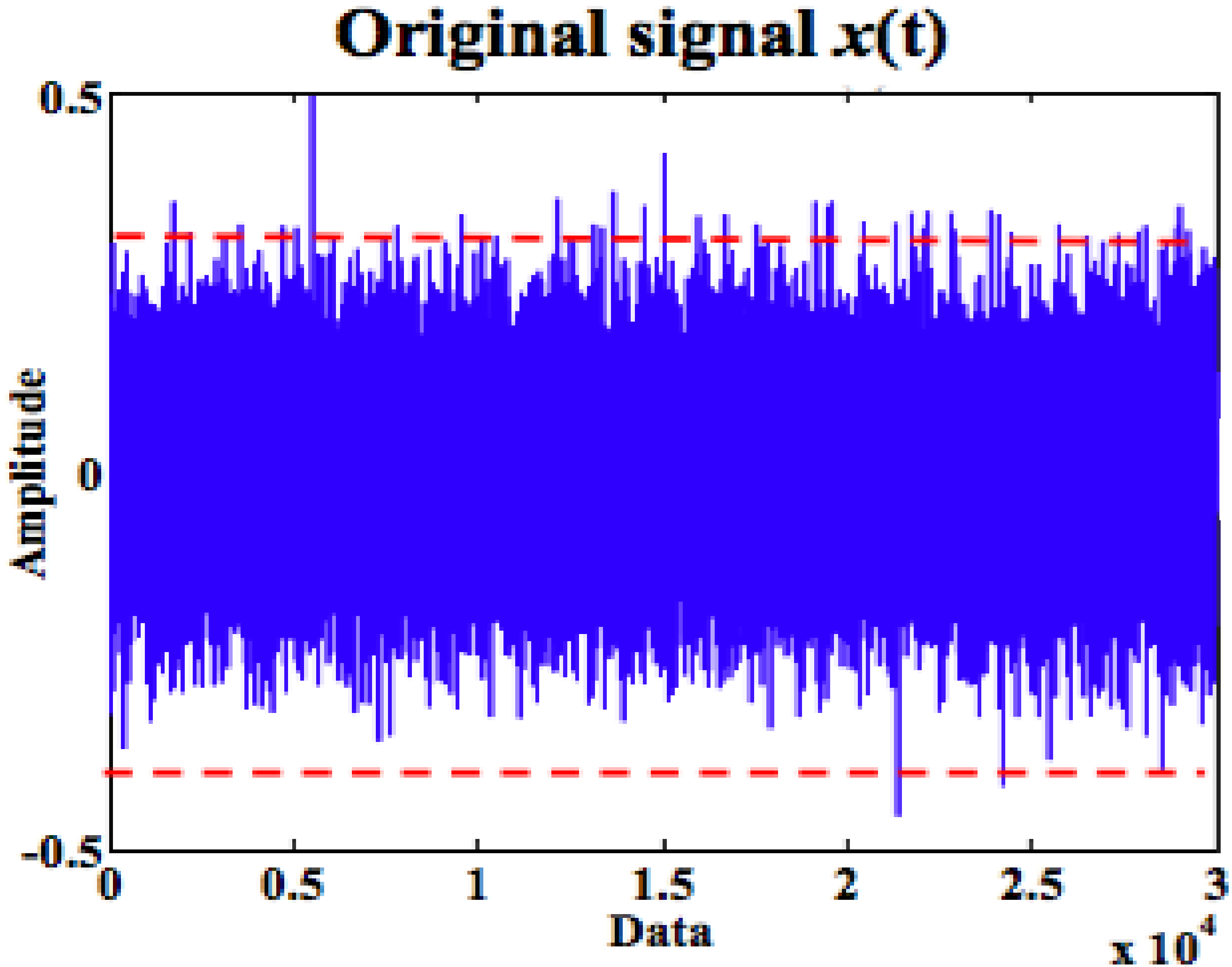
↓

However, lower modulation depths will lead to higher system BERs because of the reduction of the valid signal power.

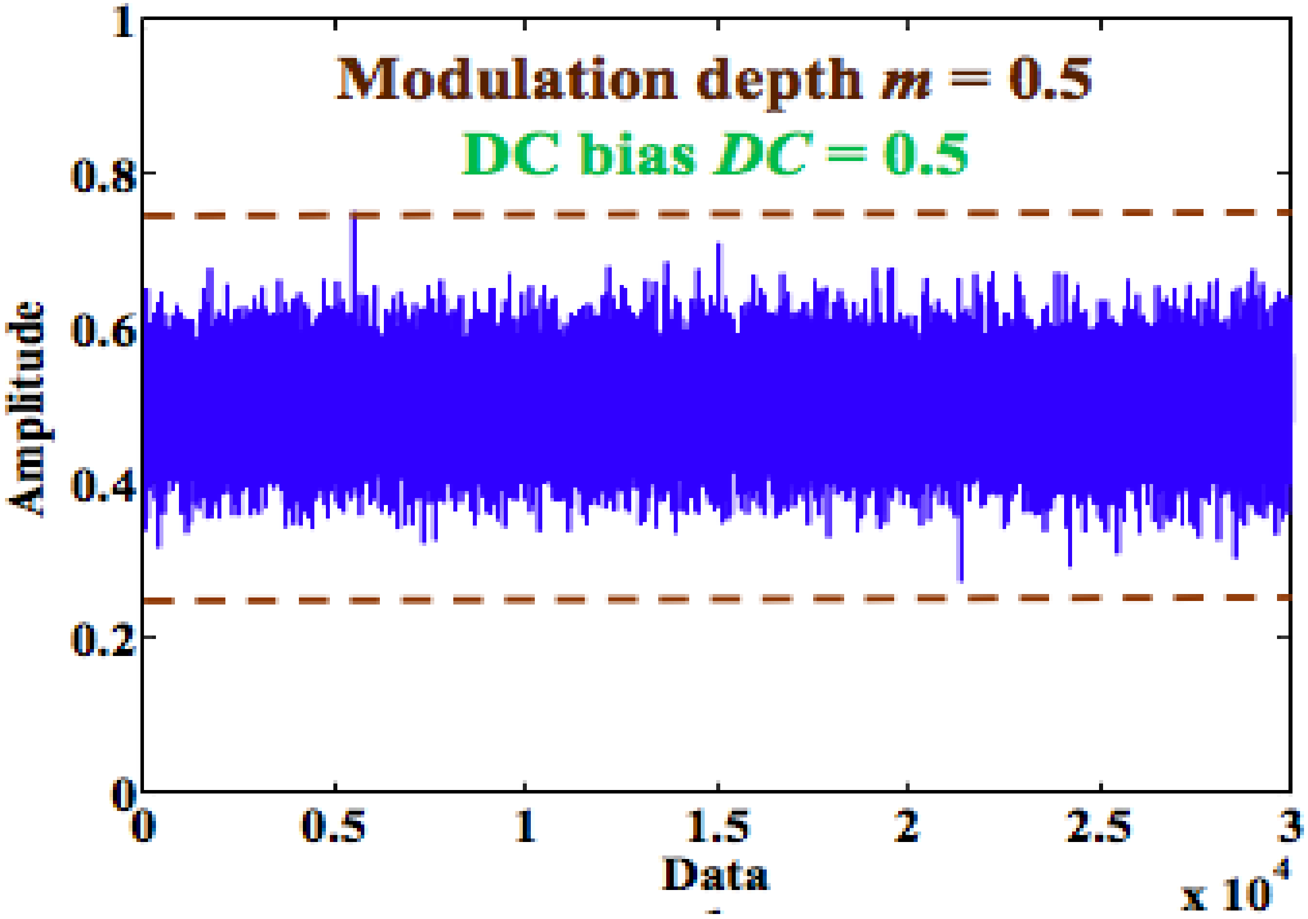
↓

Beneficial clipping method is proposed to enhance the system performance.

An example of OFDM signal

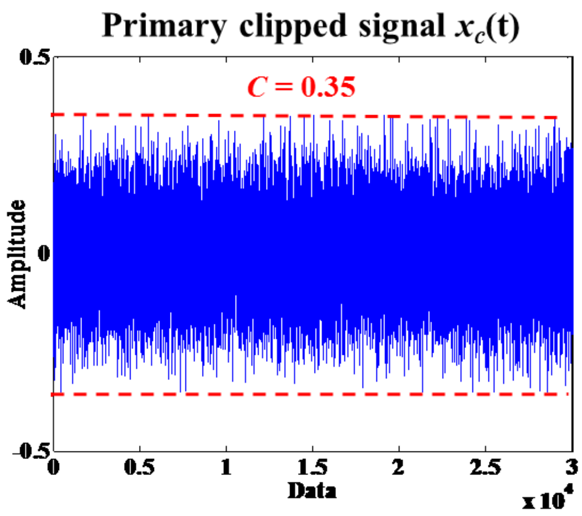


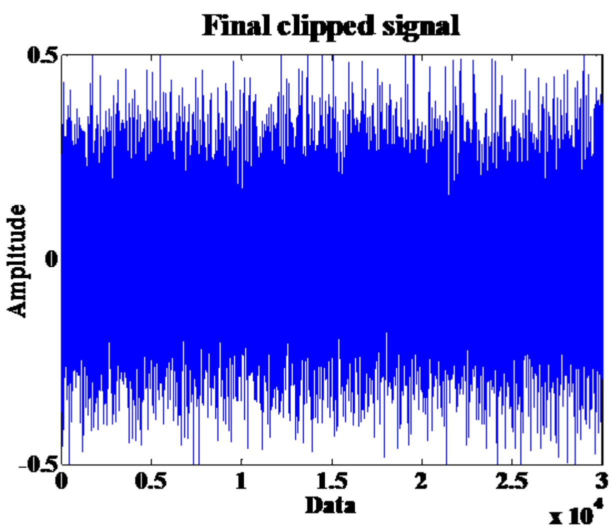
OFDM signal with DC



The beneficical clipping method

System analysis:





From the Bussgang theorem, the clipped signal $x_c(t)$ is composed of two parts: the linear attenuation $Kx(t)$ and the clipping noise $n_c(t)$:

$$x_c(t) = Kx(t) + n_c(t)$$

The expand process:

$$x_{cc}(t) = \frac{Ax_c(t)}{C} = \frac{x_c(t)}{CR}$$

$$CR = C / A$$

A: Maximum signal amplitude
CR: Clipping ratio
C: reduced amplitude after clipping

The beneficical clipping method

System analysis:

$$SNR = \frac{\sigma_{val}^2}{\sigma_{nval}^2 + \sigma_{nvlc}^2}$$

The system SNR is determined based on the signal power $(\sigma_{val})^2$, the clipping noise power $(\sigma_{nval})^2$, and the optical optical wireless channel noise $(\sigma_{nvlc})^2$

The beneficial clipping method

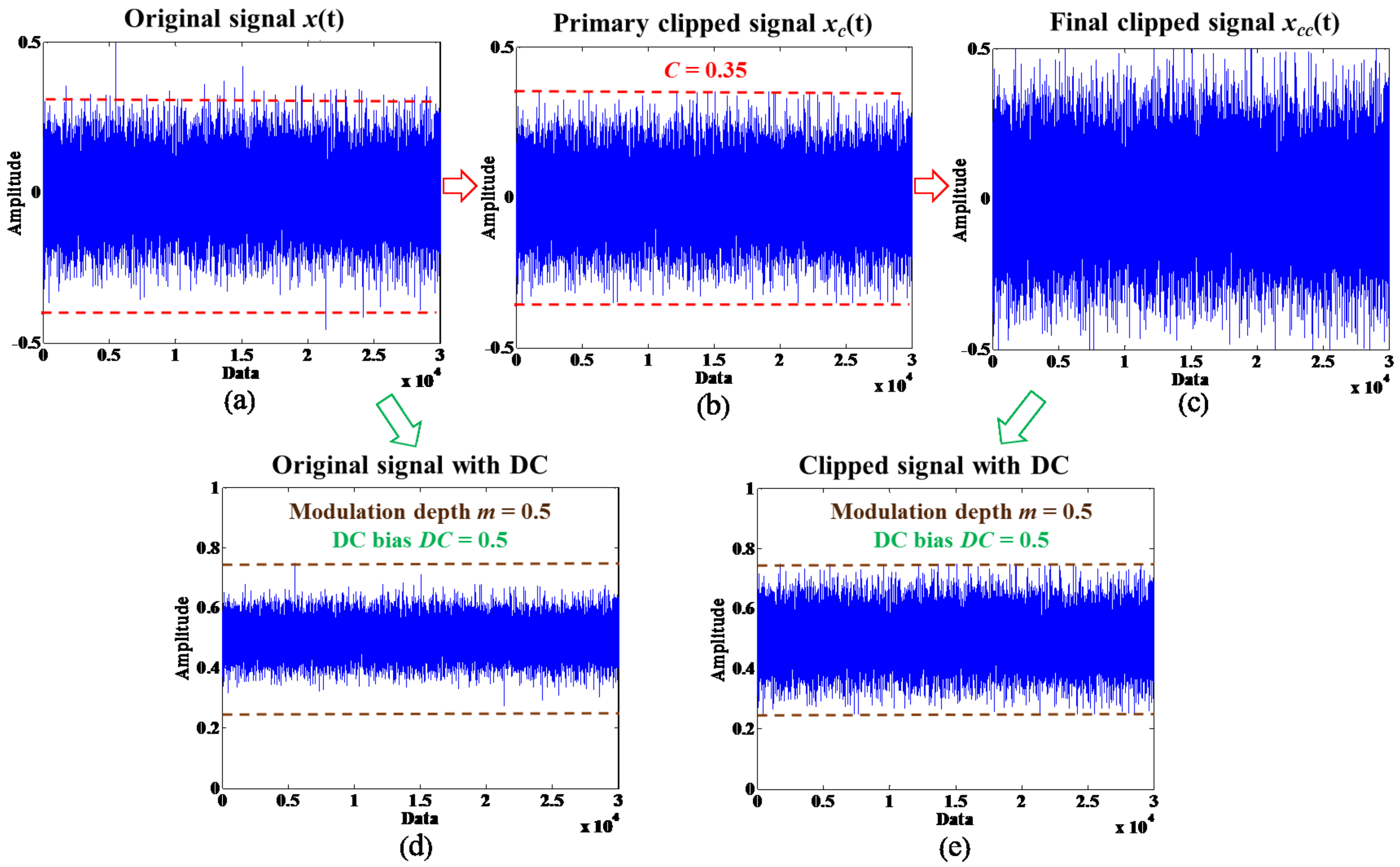
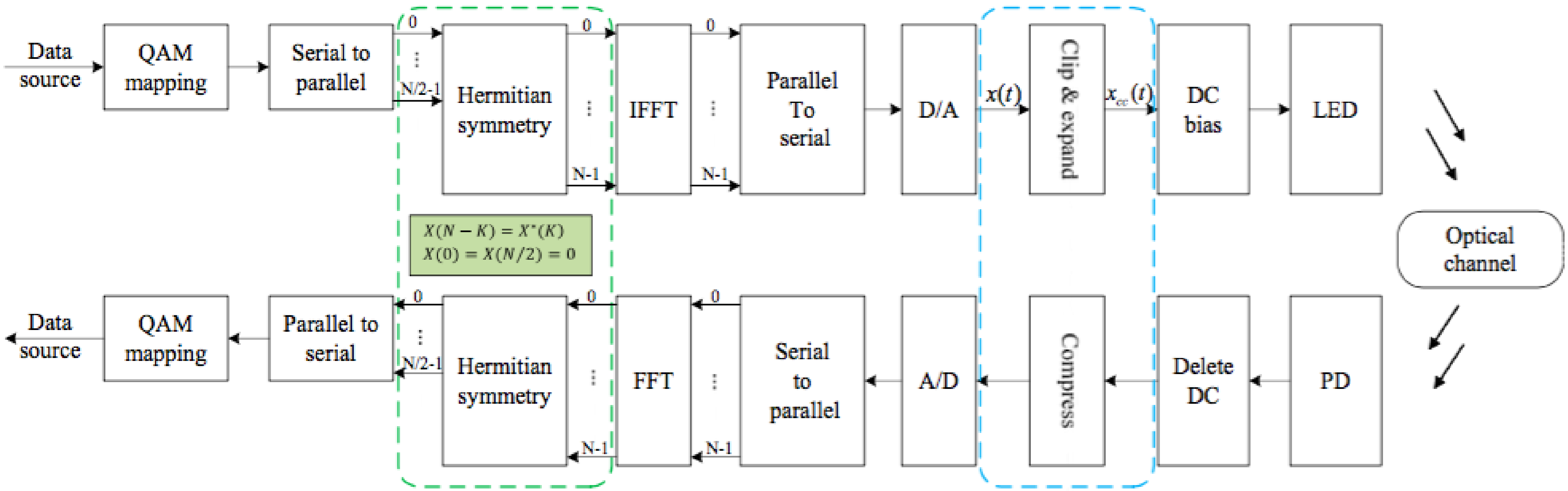
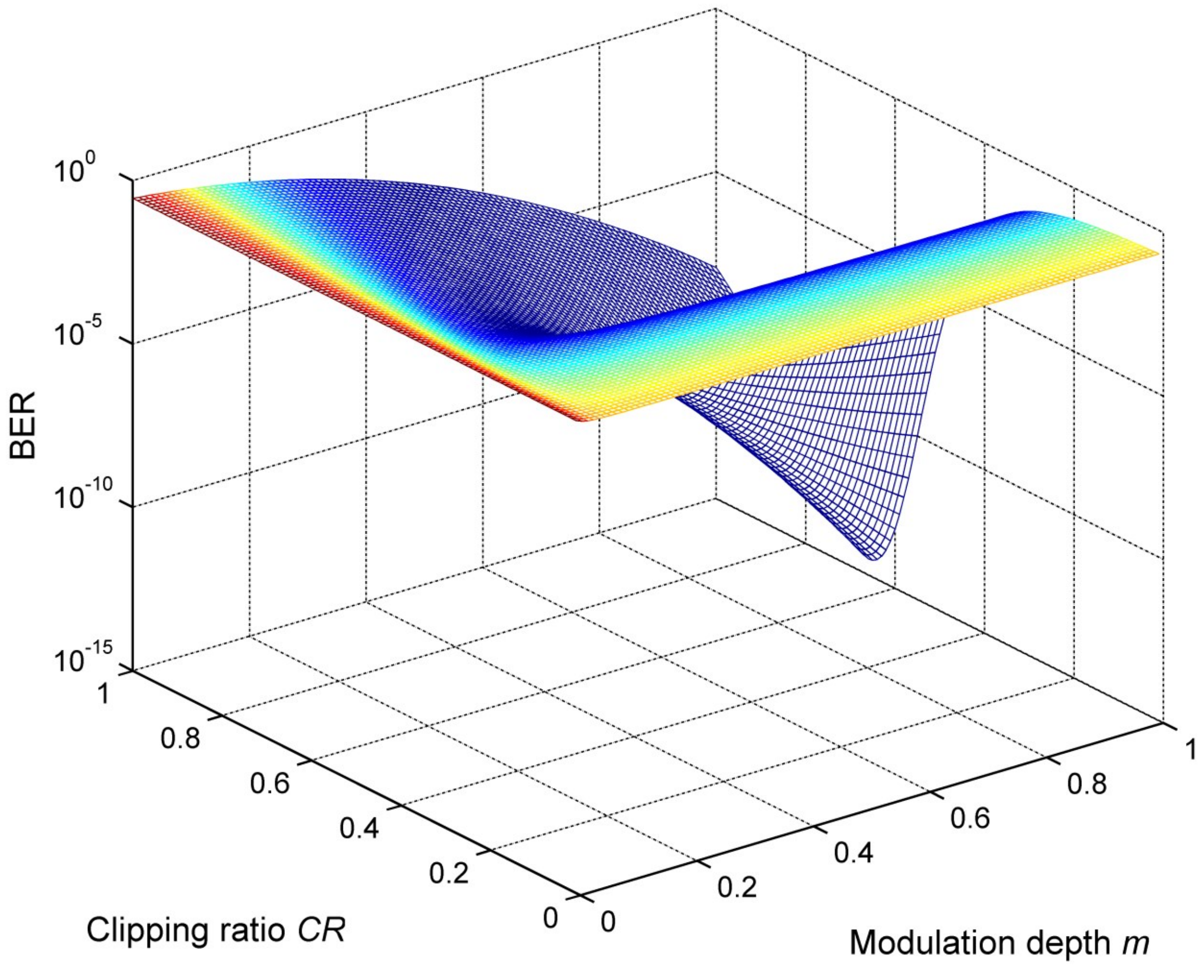


Diagram of the IM/DD DCO-OFDM system



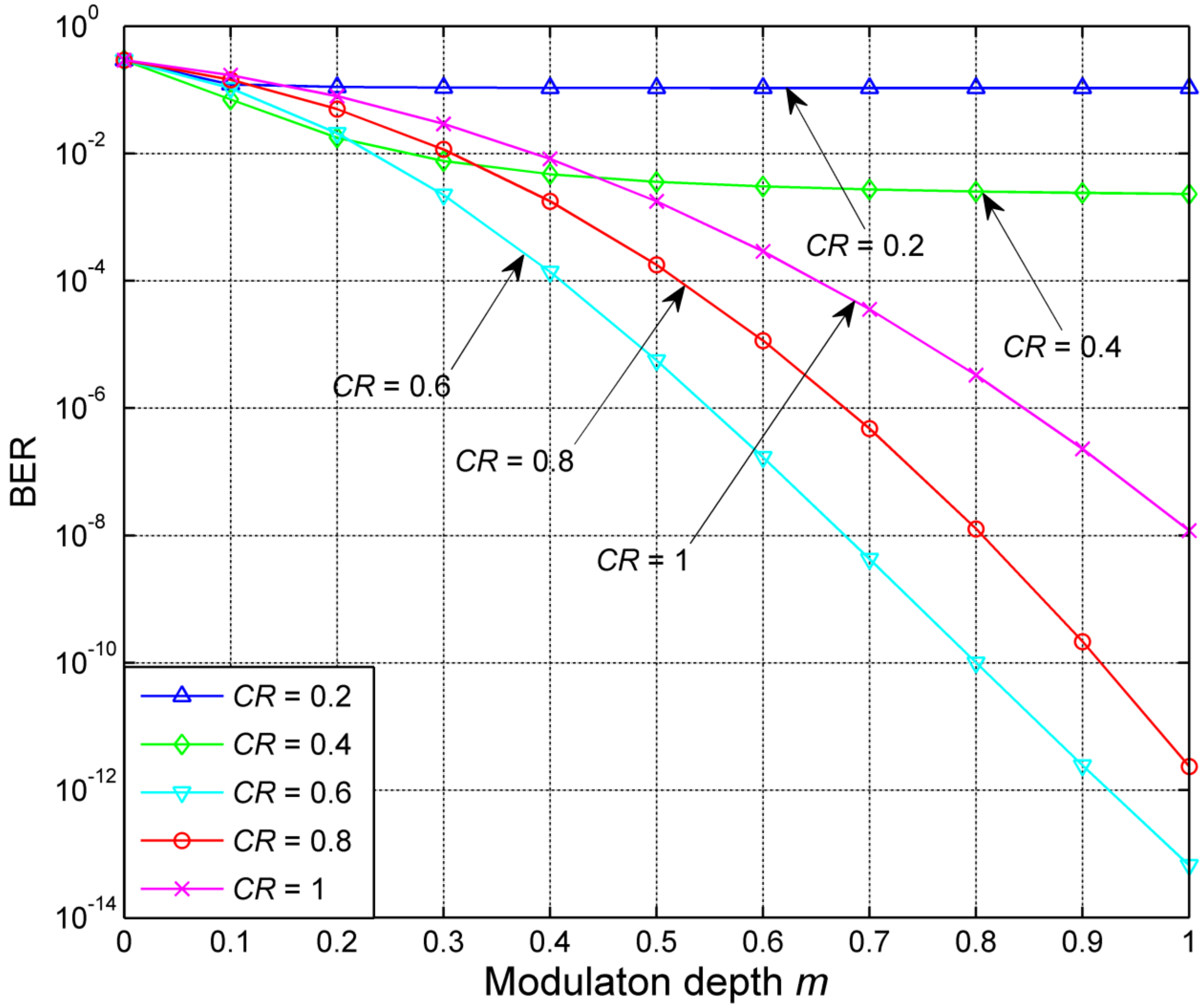
Results and conclusion



BER performances for different clipping ratios and Modulation depth.

SNR (no beneficial clipping) is set as 25dB.

Results and conclusion



BER performances for different modulation depths.

Results and conclusion

For a certain modulation depth, the beneficial clipping method can reduce the system BER and enhance system performance.

In addition, the method also can be used to obtain low modulation depths for specific BER requirements.

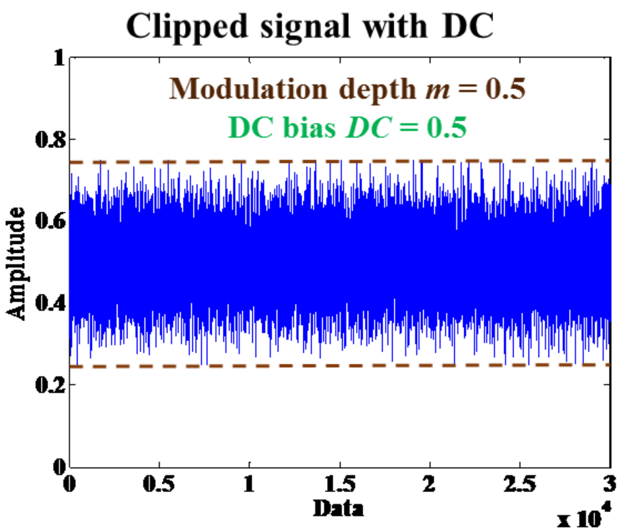
Since more international standards are needed to support the VLC-OFDM system, in the future we plan to further pursue contributions to the standardization of VLC system.

Thank you!

Any question?

The beneficical clipping method

System analysis:



The transmitted signal in the LEDs is $x_{tr}(t)$,

$$x_{tr}(t) = x_{cc}(t)m + DC$$

$$\begin{aligned} x_{elec}(t) &= x_{cc}(t)m = \frac{m}{CR}x_c(t) \\ &= \frac{Km}{CR}x(t) + \frac{m}{CR}n_c(t) \\ &= x_{val}(t) + n_{val}(t) \end{aligned}$$

$$SNR = \frac{\sigma_{val}^2}{\sigma_{nval}^2 + \sigma_{nvlc}^2}$$

The system SNR is determined based on the valid signal power $(\sigma_{val})^2$ from $x_{val}(t)$, the valid clipping noise power $(\sigma_{nval})^2$ from $n_{val}(t)$, and the optical optical wireless channel noise $(\sigma_{nvlc})^2$