CHAPTER 4
RESULT AND DISCUSSION

This chapter presents the results of the experiments that were conducted based on the method that have been described in Chapter 3. The data obtained throughout the experiments were analyzed and interpreted. The analysis will be focused on the performance of visible light communication systems based on the power, voltage and current at the transmitter and receiver.

4.1. Amplifier Effect to VLC System

In this subsection the analysis are devided into two parts. The first part is the effect of the VLC performance and the characteristic of the signal waveform before the amplifier. The second is the effect of the VLC performance and the characteristic of the signal waveform after the amplifier.

4.1.1. Measurement Before The Amplifier

To compare the performance of VLC system, the power, voltage, current, and optical power loss have been measured. The measurement was taken at 5 cm of distance between the transmitter and receiver. Figure 4.1 shows the measurement set of VLC system which has been used to observe the performance of VLC system before the amplifier at the transmitter and receiver.

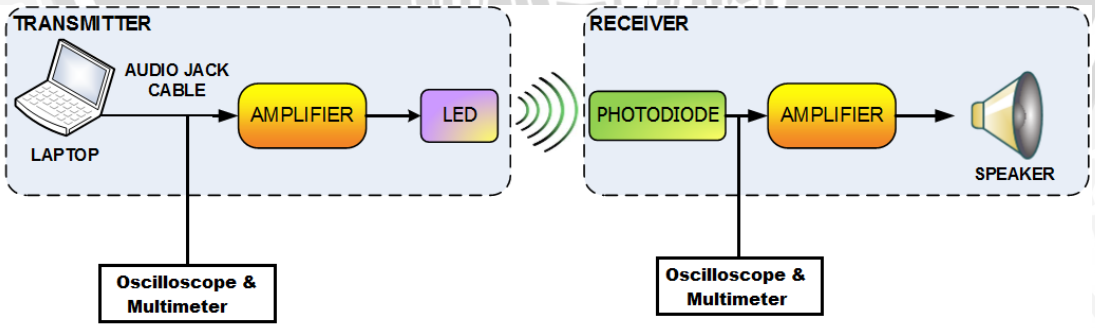


Figure 4.1 Measurement set for before the amplifier

The calculation of the power at the transmitter and also receiver has been calculated as follow :

$P_{transmitter}$ = V x I

= 3,01 mV x 0,17 mA

$= 0{,}51\ \mu W$

$= 5{,}1 \times 10^{-4}\ mW$

$P_{receiver} = V \times I$

$= 0{,}01\ mV \times 0{,}02\ mA$

$= 0{,}2 \times 10^{-3}\ \mu W$

$= 0{,}2 \times 10^{-6}\ mW$

4.1.2. Characteristic of The Signal Waveform Before The Amplifier

In this subsection will be shown the signal waveform which has been measured using oscilloscope at the transmitter and the receiver before employing the amplifier.

Figure 4.2 shows the characteristic of the signal waveform which has been transmitted by transmitter and Figure 4.3 shows the characteristic of signal waveform which has been received by photodetector. Both signal waveforms have been captured before employing the amplifier circuit.

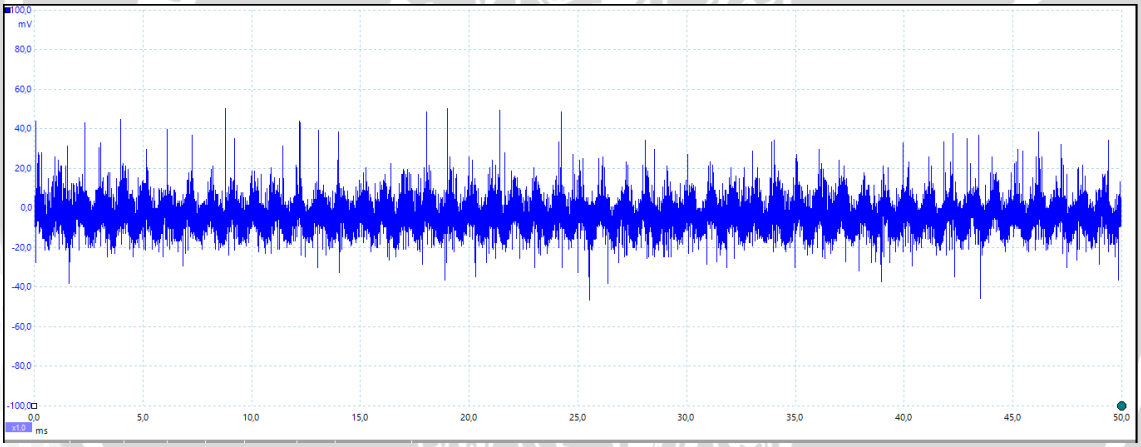


Figure 4.2 Characteristic of the signal waveform before an amplifier at the transmitter

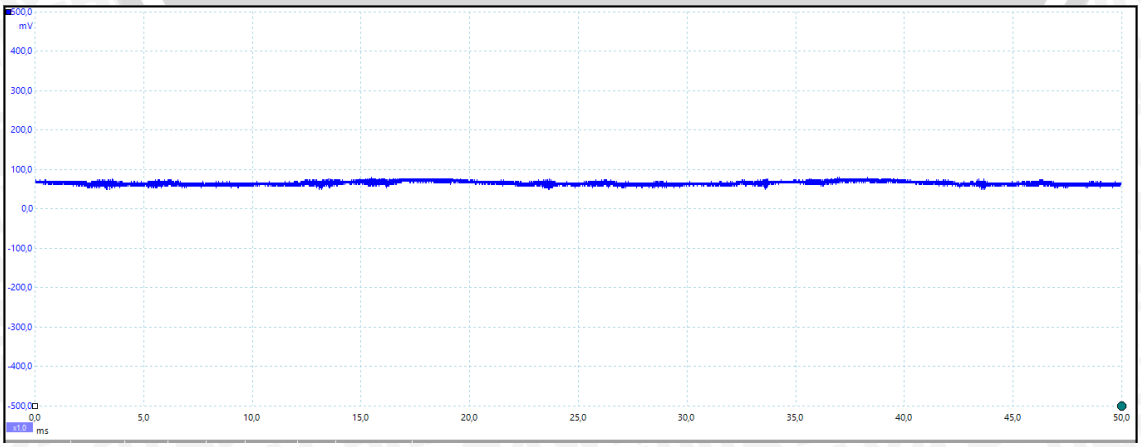


Figure 4.3 Characteristic of the signal waveform before an amplifier at the receiver

Figure 4.2 shows the characteristic of the signal waveform before an amplifier at the transmitter and also receiver. From this results we can see that the signal quality is too low. Despite when we do the transmission we can't hear the audio clearly. So from this results we conclude that we need additional amplifier at the transmitter and also at the receiver.

4.1.3. Measurement After The Amplifier

Figure 4.4 shows the measurement set of VLC system which has been used to observe the performance of VLC system after we employed the amplifier at the transmitter and receiver.

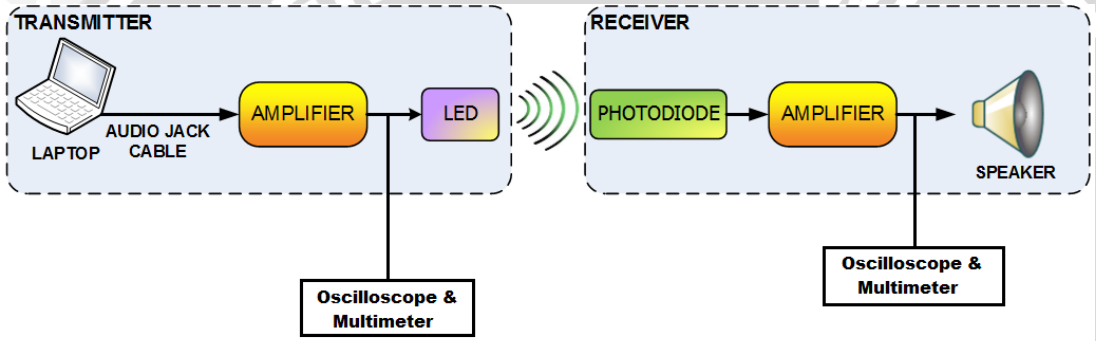


Figure 4.4 Measurement set for after the amplifier

The calculation of the power at the transmitter and also receiver has been calculated as follow :

$P_{transmitter}$ = V x I
= 1780 mV x 27,15 mA
= 48327 µW
= 48,33 mW

$P_{receiver}$ = V x I
= 2,71 mV x 0,03 mA
= 0,08 µW
= 0,8 x 10^{-4} mW

4.1.4. Characteristic of The Signal Waveform After The Amplifier

Figure 4.5 and 4.6 shows the signal waveform that have been captured after an amplifier at the transmitter and receiver.

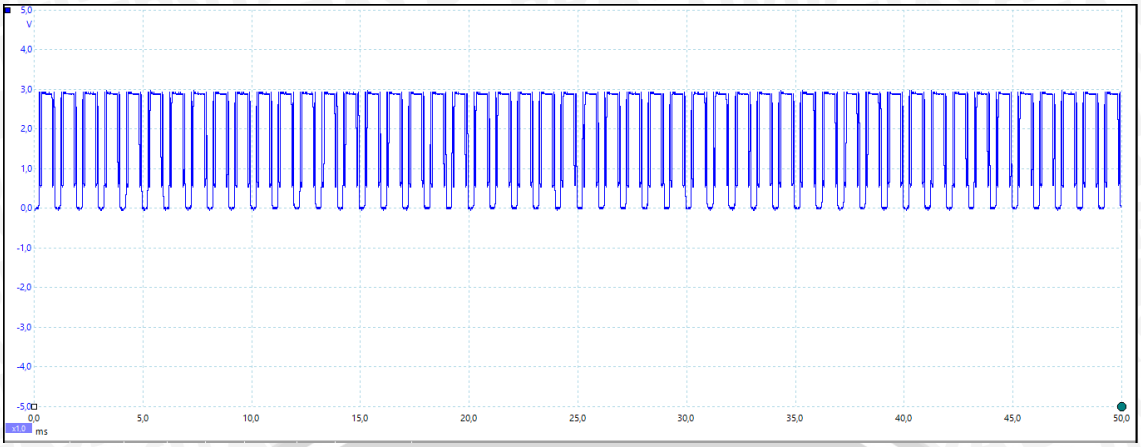


Figure 4.5 Characteristic of the signal waveform after an amplifier at the transmitter

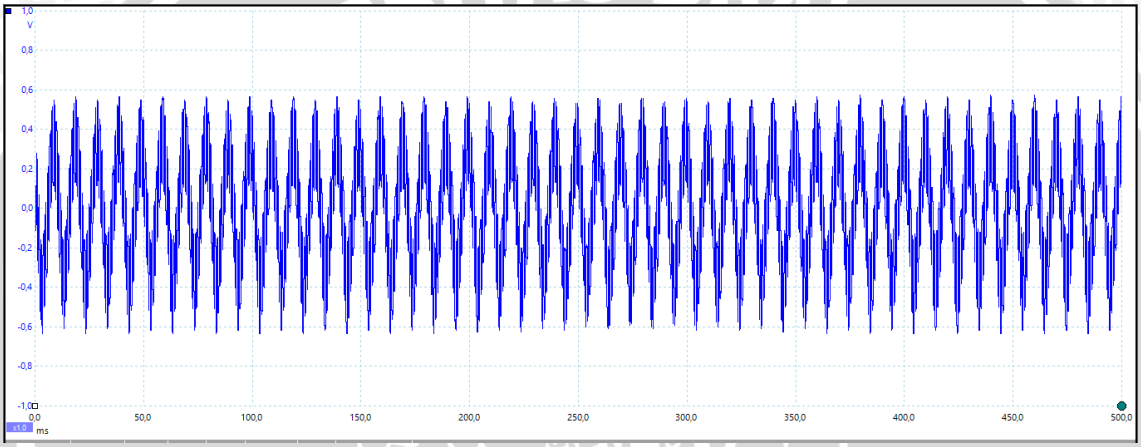


Figure 4.6 Characteristic of the signal waveform after an amplifier at the receiver

Based on the Figure 4.5 at the transmitter and Figure 4.6 at the receiver, the amplitude peak to peak which has been transmitted is 2.62 V peak to peak and the reading at the receiver is 1 V peak to peak. In addition of amplifier at the transmitter and also at the receiver on VLC system can make amplitude peak to peak increased. So it helps to increase the signal strength at the transmitter and receiver.

4.1.5. Summary of The Measurement Before and After The Amplifier

The summary of the measurement result before the amplifier in subsection 4.2.1 and the measurement after the amplifier in subsection 4.2.3 is shown in Table 4.1.

Table 4.1 Power measurement (a) before amplifer, and (b) after amplifier at the transmitter and receiver

	Transmitter			Receiver		
	Voltage (mV)	Current (mA)	Power (mW)	Voltage (mV)	Current (mA)	Power (mW)
(a) Before amplifier	3,01	0,17	$5,1 \times 10^{-4}$	0,01	0,02	$0,2 \times 10^{-6}$
(b) After amplifier	1780	27,15	48,33	2,71	0,03	$0,8 \times 10^{-4}$

In table 4.1 (a) the calculation results shows the power at the transmitter is 5,1 x 10^{-4} mW at the receiver is 0,2 x 10^{-6} mW before the amplifier. During the transmitter, the audio signal from transmitter can't be heard clearly at the receiver part. So we decided to add the amplifier circuit at the transmitter and also at receiver.

After the amplifier have been added at the transmitter and also at the receiver, it shows that the power is increased by 48,33 mW at the transmitter and 0,8 x 10^{-4} mW at the receiver. From this results we can see that the amplifier boost the signal power at the transmitter and also at the receiver. It can increasing the voltage from transmitter and also receiver.

4.2. Distance Effect to VLC System

In this subsection the analysis are devided into two parts. The first part is the effect of various distance againts the VLC performance. The second is the effect of various distance againts the characteristic of the signal waveforms.

4.2.1. Measurement of The VLC Performance

The various between the distance of transmitter and receiver are observed to see the performance of visible light communication system for audio transmission. The calculation of the power at the transmitter and receiver have been shown clearly in this section. The optical power loss of the system has also been calculated at various distance at 5 cm, 10 cm, 15 cm, and 20 cm as follow :

i. Distance = 5 cm

$P_{transmitter}$ = V x I

= 3,01 mV x 0,17 mA

= 0,51 µW

= 5,1 x 10^{-4} mW

$P_{receiver}$ = V x I

= 2,71 mV x 0,03 mA

= 0,08 µW

= 0,8 x 10^{-4} mW

Loss = 10 log $\frac{P\ receiver}{P\ transmitter}$

= 10 log $\frac{0{,}8 \text{ x } 10-4}{5{,}1 \text{ x } 10-4}$

= – 8,04 dB

ii. Distance = 10 cm

$P_{transmitter}$ = V x I

= 3,01 mV x 0,17 mA

= 0,51 µW

= 5,1 x 10^{-4} mW

$P_{receiver}$ = V x I

= 1,25 mV x 0,03 mA

= 0,04 µW

= 0,4 x 10^{-4} mW

Loss = 10 log $\frac{P\ receiver}{P\ transmitter}$

= 10 log $\frac{0{,}4 \text{ x } 10-4}{5{,}1 \text{ x } 10-4}$

= – 11,06 dB

iii. Distance = 15 cm

$P_{transmitter}$ = V x I

= 3,01 mV x 0,17 mA

= 0,51 µW

= 5,1 x 10^{-4} mW

$P_{receiver}$ = V x I

= 0,87 mV x 0,03 mA

= 0,03 µW

= 0,3 x 10^{-4} mW

Loss $= 10 \log \frac{P\ receiver}{P\ transmitter}$

$= 10 \log \frac{0{,}3 \text{ x } 10-4}{5{,}1 \text{ x } 10-4}$

$= -12{,}3$ dB

iv. Distance = 20 cm

$P_{transmitter}$ = V x I

= 3,01 mV x 0,17 mA

= 0,51 µW

= 5,1 x 10^{-4} mW

$P_{receiver}$ = V x I

= 0,36 mV x 0,03 mA

= 0,01 µW

= 0,1 x 10^{-4} mW

Loss $= 10 \log \frac{P\ receiver}{P\ transmitter}$

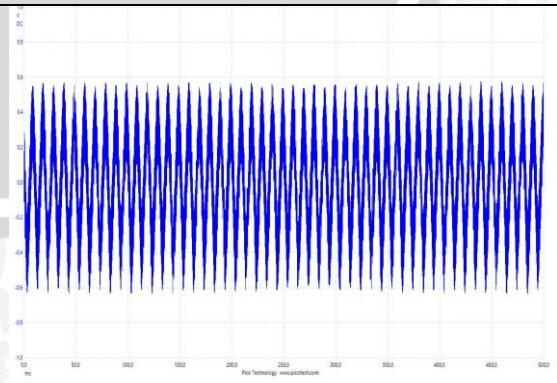
$= 10 \log \frac{0{,}1 \text{ x } 10-4}{5{,}1 \text{ x } 10-4}$

$= -17{,}08$ dB

4.2.2. Characteristic of The Signal Waveforms

This subsection shown the signal waveforms which has been measured using oscilloscope at transmitter and receiver with the variation of distance.

Table 4.2 Characteristic of signal waveforms on distance effect to VLC system

Distance	Transmitter	Receiver
5 cm		 (b)

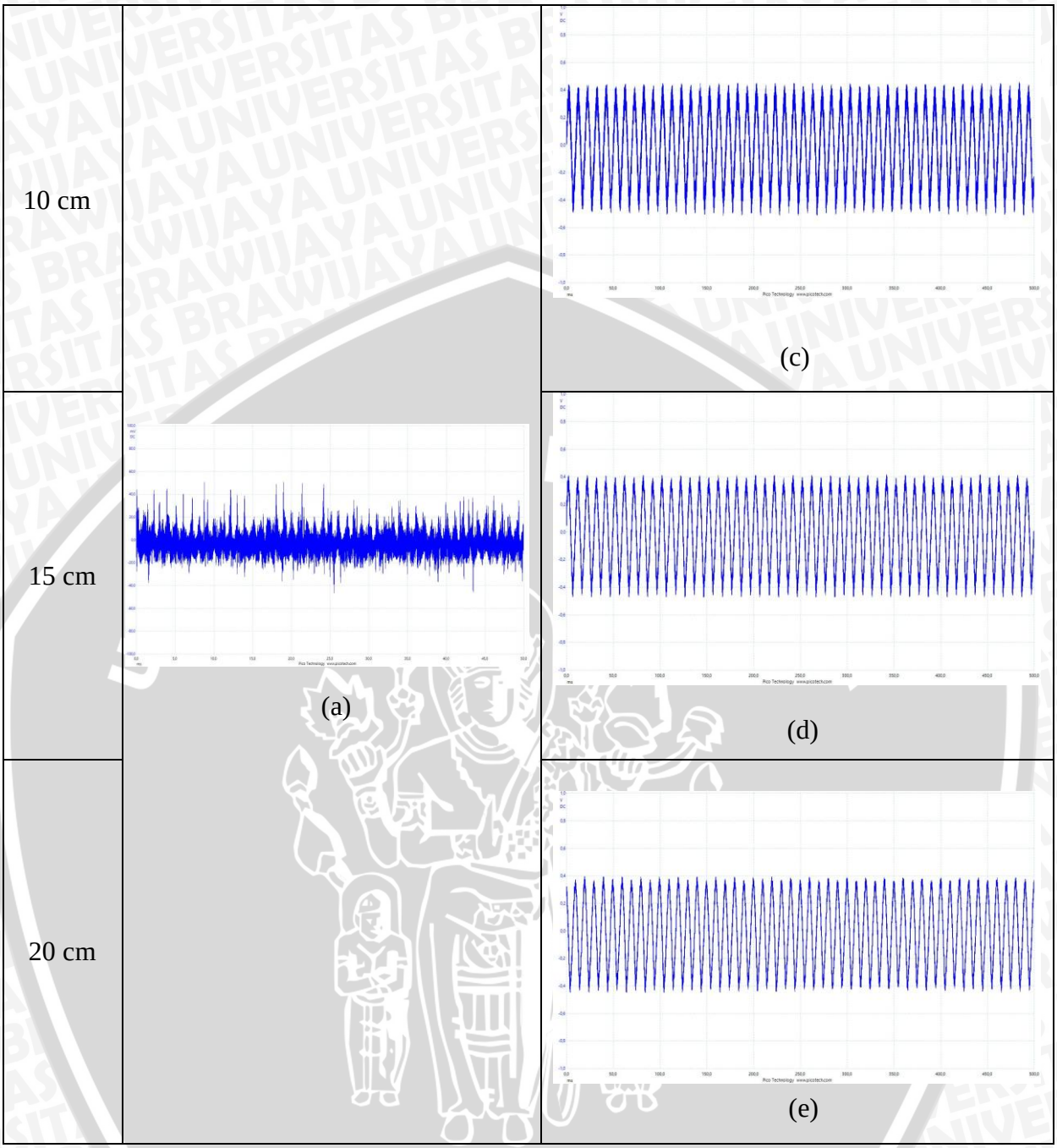


Table 4.2 (a) shows the characteristic of the signal waveforms which have been transmitted and Table 4.2 (b), (c), (d), (e) shows the characteristic of signal waveforms which have been received by photodetector with variation of distance. The measurement was taken at 5 cm, 10 cm, 15 cm, and 20 cm of distance between the transmitter and receiver.

From this results we can see that the distance between the transmitter and receiver on VLC system can effects the signal strenght. If the distance between transmitter and receiver is greater the signal strength will be smaller. We can see in table 4.2 (b), the

highest peak to peak voltage at the receiver occurs at 5 cm of distance. At this distance we can hear the audio clearly with additional noise. In other hand, when we do the transmission over 20 cm of distance, we can't hear the audio clearly because this system have lowest peak to peak voltage as shown in figure 4.2 (e).

4.2.3. Summary of The Distance Effect to VLC System

Based on the calculating of the measurement of the VLC performance which has been discussed in subsection 4.3.1, the summary result of the calculating is shown in Table 4.3.

Table 4.3 Power and loss measurement on transmitter and receiver with variation of distance

Distance	Transmitter			Receiver			Loss (dB)
	Voltage (mV)	Current (mA)	Power (mW)	Voltage (mV)	Current (mA)	Power (mW)	
5 cm	3,01	0,17	$5,1 \times 10^{-4}$	2,71	0,03	$0,8 \times 10^{-4}$	– 8,04
10 cm				1,25	0,03	$0,4 \times 10^{-4}$	– 11,06
15 cm				0,87	0,03	$0,3 \times 10^{-4}$	– 12,3
20 cm				0,36	0,03	$0,1 \times 10^{-4}$	– 17,08

Based on the calculation result which has been shows in Table 4.3, the optical power loss at 5 cm, 10 cm, 15 cm, and 20 cm have been increased simultaniously from – 8,04 dB to – 17,08 dB.

From this results we can see that the parameter of distance between transmitter and receiver can influence the value of voltage, power, and optical power loss. We observed the optical power loss is increased as the distance between transmitter and receiver are increased. This is because the sensitivity of the photodetector are less sensitive at the longer distance.

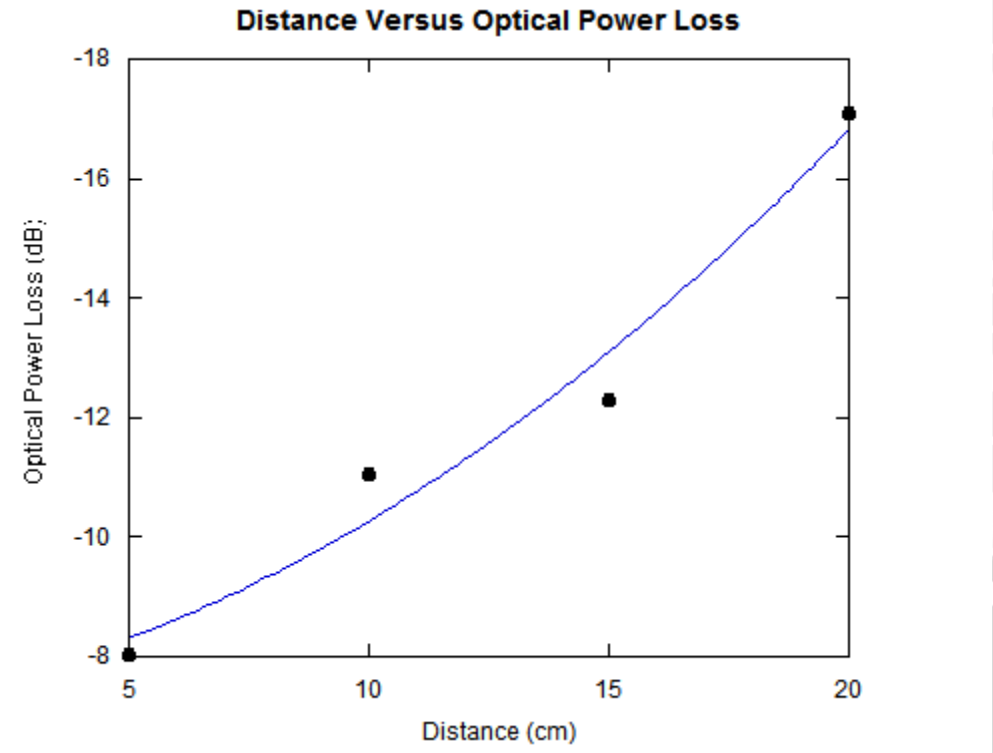


Figure 4.7 Graphic characteristics of distance versus optical power loss

Figure 4.7 shows the relation between optical power loss and distance between transmitter and receiver in VLC system. This figure shows longer the distance, means higher optical power loss. It caused by in the transmission process from the transmitter to receiver, the signal suffered the scattering and absorbtion process.