Preliminary Experimental Results along a Horizontal Path for Adaptive Rate-controlled FSO

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Abstract— Free-space optical communication is a focus in recent research. Because of the influence of weather conditions, the transmission channel of free-space optical communication dramatically changes. This paper describes the design of a new adaptive rate-controlled optical communication system. The rate adaptively changes through the estimation of the received signal strength. Usually estimate the channel conditions with a low rate of radio frequency feedback. Previously the author used a new technique to design an adaptive rate-controlled optical communication system. It used beacon calibration instead of radio frequency feedback. In this paper an outdoor experiment is performed along a 186 meters horizontal path. On-off Keying modulation is used. The preliminary results with adaptive rate control are compared with that of without adaptive rate control. It appears to be at least an order of magnitude decrease of the bit-error rate.

1. INTRODUCTION

For a long time, people try to communicate over long distances by free-space optical communication (FSO) [1]. Long distance communications are often faced with the problems of confidentiality and spectrum resources. Microwave and radio frequency (RF) communications tend to saturate. With the exploration of outer space, the need of communication will be stronger. In general, communication wavelength is proportional to the volume of communication equipment. Shorter wavelength means smaller volume of the equipment. So the short wave communication, such as optical communication, can use a telescope as antenna. But the longer wavelength communication needs to use larger size antenna that we usually placed on the roof. Smaller volume means less power consumption. As to the outer space satellite, it is very important.

If we count the days from the research of Soviet Union in the last century, the development of optical communications has experienced at least 60 years. If we count the days from the Baer's era, this time is even longer. Initially, the optical communication faces two major problems: one is light source, and the other is transmission medium. Free-space optical communication has not the same good luck of fiber communication. In FSO communication, the transmitter and the receiver are likely to be moving targets. This provides a great technical problem for the FSO. FSO needs to solve the technical problem of acquisition, tracking and pointing (ATP) [2]. The applications of ATP technology are generally based on a national strategy. Therefore, this technology greatly increases the cost of equipment and limits its large-scale commercial applications. FSO needs to solve another problem. Its transmission medium is extremely unstable, and can produce very bad effect. The most obvious example is the optical scintillation. There are many researches about this issue, such as Ref. [3]. As a result, FSO has a low transmission rate and a short transmission distance. High-speed and long-distance transmission leads to high bit-error rate. Due to the above difficulties, FSO has not yet received a large-scale commercial application. As to FSO, firstly promoting short distance communication between roofs is a more feasible development direction. After the market and demand are mature, it can be extended to ground-to-space or the space-to-space cases.

Due to weather conditions, even if in a 1–2 kilometers distance, FSO is difficult to communicate. The most often solution is to use radio frequency feedback technology. It uses radio frequency signal to detect channel conditions. Refs. [4–7] gives theoretical analysis and system designs of adaptive rate-controlled optical communication system.

Reference [8] use another technique to detect the channel conditions in an indoor experiment is performed. This technique is based on the beacon light calibration. The second part of the paper introduces the operation principle of the adaptive rate-controlled optical communication system. The third part introduces experimental results of outdoor 186 meters horizontal propagation.

2. OPERATION PRINCIPLE

Traditional FSO is based on direct detection. When designs and tests the circuit, this type of FSO confronts a problem: due to the channel scintillation, the optical signals are very weak and are drowned in the noise. Threshold mechanism decides that the traditional FSO can not work efficiently.

The author develops an adaptive rate-controlled FSO system. The flow chart of its operation principle is shown in Fig. 1.

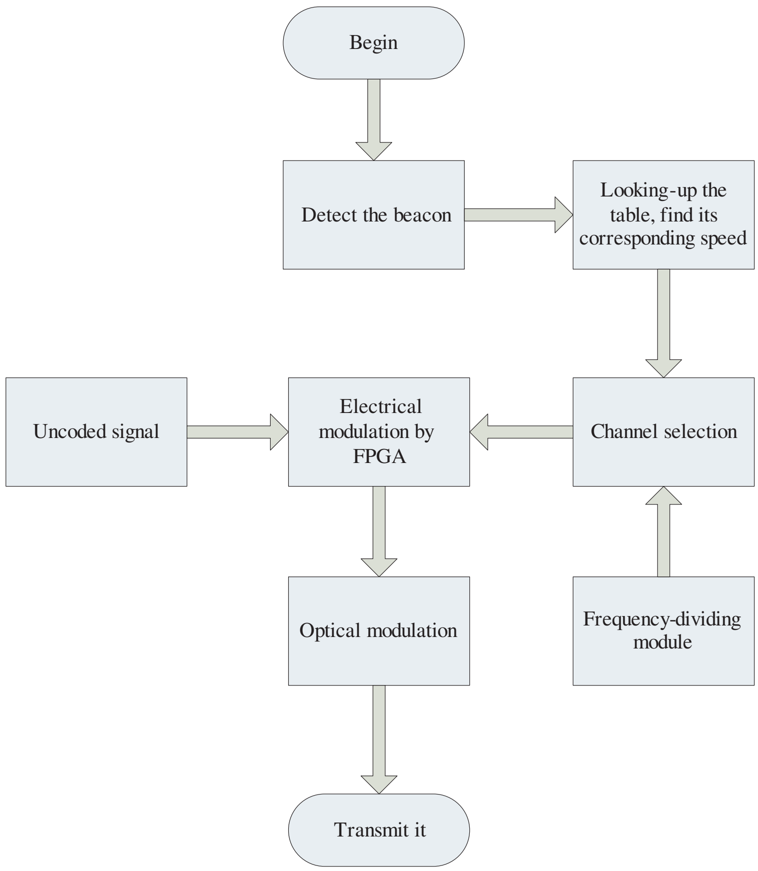

Figure 1: The operation flow chart of adaptive rate-controlled FSO.

The beacon is transmitted to the transmitter. The beacon is a cooperative laser. The transmitter detects and amplifies the beacon. Decides its optical power, looks up the table and decides its speed. Produces the same speed modulated signal, modulates the laser, and transmits it.

In other people's work, RF feedback is usually used to decide the channel conditions. Different from that, in our design, the transmitter continuously detects, amplifies and codes the beacon. In the atmospheric environment, 1 Gbit/s is a very high transmission speed. This situation usually means a very weak turbulence, such as the top of mountain. The transmitter will divide the system clock into 16 frequencies from 250 MHz–1 GHz. The FSO system designed in this paper gives 16 transmission speeds, which correspond to 16 channels from 250 Mbit/s–1 Gbit/s. Because the magnification is fixed, assuming that the detected voltage is 1.78 V, we assign that the 500 MHz channel is opened, and the other ones are closed. Then FPGA carries the encoded signal onto the open channel. The above is the process of electrical modulation. Next the electrical modulated signals are sent to the optical modulator and transmitted.

The power calibration technique of the beacon is introduced in Ref. [8].

3. 186 m HORIZONTAL PROPAGATION EXPERIMENT RESULTS

The authors perform a 186 m horizontal propagation experiment. The light propagation path is selected between the tops of two buildings of Hubei University as shown in Fig. 2.

The time of the experiment is at the mornings of August 13–15, 2013. A transmitter and a receiver are placed on the tops of two respective buildings. The distance between the beams and

Figure 2: An aerial photograph of the light propagation path (from Baidu map).

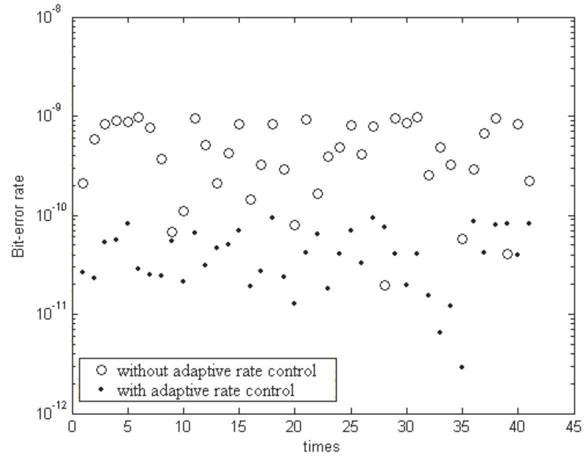

Figure 3: Comparison results.

the ground is nearly 24 meters. The diameters of the transmitter and the receiver are 10 cm. The wavelength of the beacon is 650 nm. The modulation frequency of the beacon is 5 kHz. The beacon's calibration time is at midnights. The beacon is placed at the end of the receiver and is transmitted to the transmitter. After the transmitter detects the beacon, the processing circuit decides the channel fluctuation conditions. Then an OOK (on-off keying) modulated signal is transmitted towards the receiver. The transmission speed is adjusted from 250 MHz–1 GHz according to the channel conditions.

We perform alternate measurements. The first launch is a frame of data without adaptive rate-control. Its transmission rate is 500 MHz. Measure its bit-error rate. Then under the control of the beacon, we emit a frame of data with rate control according to the turbulent conditions. Also we test the bit-error rate. Repeat this process. 82 frames of data are tested alternately.

The results are plotted in Fig. 3. The number of the test times is plotted along the horizontal axis. The bit-error rate is along the vertical axis. The circles are used to show the results without adaptive rate control, and the points are used for the results with adaptive rate control.

You can see from Fig. 2 that in the adaptive rate control cases, bit-error rate has an obvious improvement. Comparing with the cases without adaptive rate control, bit-error rate decreases one order of magnitude with adaptive rate control. Sometimes the bit-error rate without adaptive rate control is less than that with adaptive rate control. But these cases are comparatively rare. Maybe it is because the turbulence changes its state during two launches.

4. CONCLUSIONS

In this paper, the authors establish a horizontal link with adaptive rate control. Under the OOK modulation, adaptive rate control shows its efficiency and bit-error rate improvement. Future research will compare different modulation modes.

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