Performance of Free-space Optical Communication with Feed Forward Compensation Model

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ABSTRACT
Free-space optical communication offers an attractive alternative for transferring high- bandwidth data over RF (Radio Frequency) signals. However, satellite vibration is the major pointing error. Without compensating for it, the optical communication terminal cannot achieve accurate and stable links. The effect of this phenomena leads to the misalignment between the transmitter and the receiver, decrease in the received signal and increase in BER (Bit Error Rate). With this in mind, this paper examines the effect of satellite vibration on optical link and develops a BER model that takes the satellite vibration into account. Then, a feed- forward vibration compensation model under fine tracking mode is designed to decrease this residual jitter influences. The results show that the proposed method is simple and effective, and the vibration amplitude can be decreased greatly.

Keywords
Pointing Errors, Feed forward compensation, Bit Error Rate

1. INTRODUCTION
Free-space optical communication, a natural development of space communication to be expected during the next decade, offers greater advantages over traditional Radio Frequency (RF) signals such as large data rate, low probability of detection and interception, and less power consumption. Though the advantages of a directional laser beam used in this system are beyond question, some problems must be solved. Continuous movement of the satellites results from internal mechanical sources and external environment causes vibrations for both the transmitter beam and the receiver telescope (field of view), moving them from the common line of sight, which makes the pointing and tracking system complex. In addition, free-space optical communication uses optical radiation as a carrier, which enables transmission to use very narrow beam divergence (micro-radians) that makes the transmitter beam sometimes miss the companion satellite due to the pointing vibrations [1]. These factors delay the further proliferation of free-space optical communication. Because of noise in the tracking system and mechanical vibrations, the transmitter beam to the receiver satellite vibrates, and such vibrations decrease the average received signal in the receiver plane, which, in turn, increase the link Bit Error Rate.

Thus, the residual vibration influences must be considered in optical communication system. At present, most satellites rely on passive methods (vibration isolator) which can reduce vibration, but add significant weight penalty to the satellite, leaving the source of vibration uncontrolled. Alternatively, `here we present an active control method [2]. The active control method is the feed-forward compensation method. This technique is used to reduce the effects of vibrations in the pointing system. This feed forward technique is an active control method which will control these errors and pave the way for clear and delay less optical communication. This feed – forward method is very simple to design. This paper mainly deals with reduction of pointing errors which cause delay in the optical communication tracking system. This method is very efficient in reducing errors. More over this paper presents an approach to analyze the performance of optical communication system in the presence of satellite vibration and a BER mathematical model is derived, which defines BER as a function of vibration amplitude[3]. After that, a feed-forward vibration compensation model under the fine tracking mode is developed in MATLAB/ Simulink to illustrate how to decrease this residual influences and give the simulation results.

2. POINTING ERRORS
The satellite is generally considered as a noisy environment. Many of the major contributors of vibration is given in table [1]. Coupling with the satellite vibrations and noise in the tracking system distorts the alignment between the transmitter and the receiver, making pointing errors in the direction of the receiving satellite and the pointing errors have a significant effect on the link performance and BER.

Table1: Major Contributors of Vibration

Internal sources	External sources
Navigation noise	Impact of micrometeorites
Thruster operation	Gravitation fields of theSun, Moon, Earth and other celestial bodies
Antenna pointing mechanism	Solar radiation pressure
Tracking noise	Satellite structure bending due to temperature differences

3. BIT ERROR RATE
In this link IM/DD (Intensity Modulation/Direct Detection) ON/OFF keying is adopted. The receiver includes an optical detector and converts the optical power to electronic signals with conversion ratio of *R*. The receiver integrates the signal and determines whether the signal is ON or OFF.

Here, define the relative electronic signal as y before making decision. In addition, assume that the noise is independent of the received signal, with zero mean [5]. The signal y corresponds to the following conditional densities when the bit is ON or OFF.

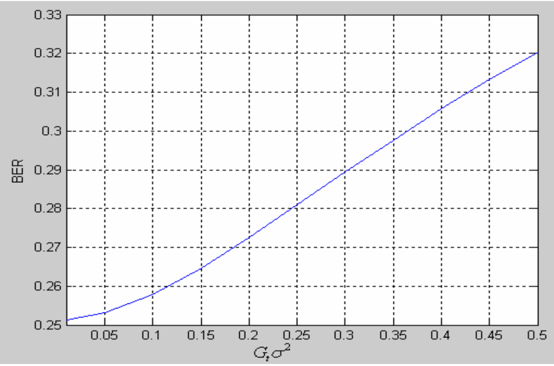

Fig 1:BER as a function of the transmitter gain

In the following section a feed-forward vibration compensation model is developed under the fine tracking mode with MATLAB/Simulink tool to decrease this vibration effects. Vibration feed-forward compensation in optical communication is that when the disturbance is added to the output, feedback this signal to the input which can counteract the impact of vibration perfectly. This finely tracking model mainly consists of CCD spot detection unit and video signal processor, position compensation unit, D/A conversion unit, and speed servo close loop unit.

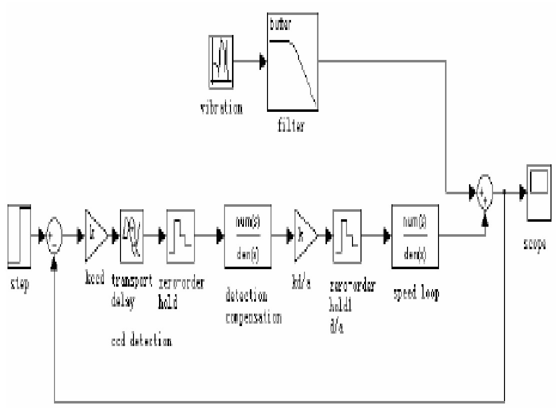

Fig. 2 shows the relation between BER and vibration amplitude after compensation. The values of amplitude in this figure (X-axis) are the compensational results, it can be seen the improvement of performance is nearly 30 times more than that of non- compensation compared with the values in Fig 1 .Fig. 3 is a comparison of BER between non-compensation and compensation cases. It is clear that the compensational results are nearly a fix value (around 0.25). The comparison result shows that the proposed control is effective to significantly reduce the vibration influences.

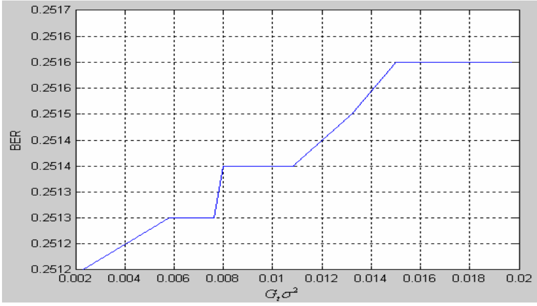

Fig 2. BER as a function of vibration amplitude after compensation

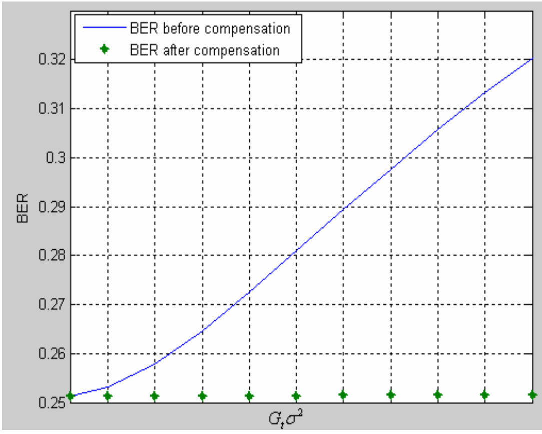

Fig. 3 Comparison of BER between non-compensation and compensation cases

4. CONCLUSION

This paper discusses the effect of satellite vibration causing pointing errors on the performance of optical communication system and gives a new feed – forward compensation model to rectify errors. The simulation results show that the vibration amplitude has great effect on BER. So, a feed-forward vibration compensation model is designed with MATLAB/Simulink. The system CCD sampling time is 20 seconds and the compensation time happens at about 3.5 second. The vibration amplitude after compensation is decreased about 30 times and BER is nearly a fix value around 0.25 compared with the non-compensation situation, in which the BER is lineally increasing with the vibration amplitude.

5. REFERENCES

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