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RESEARCH ARTICLE

JIA Dagong, WANG Guanghui, ZHANG Yimo, ZHANG Yinxin, JING Wencai, ZHOU Ge

Dynamic interconnection component using wireless infrared technology

Abstract An efficient dynamic interconnection model using wireless infrared technology and the theory of optical interconnections was constructed to design a dual-channel interconnection component. There were three conditions between the rotating optical field and the stationary optical field: end separation, angle misalignment and lateral misalignment. The calculation formulas were given for these three conditions. A dual-channel optical interconnection component was designed based on the dynamic interconnection model and the data transmission rate of the component was measured. The experimental result showed that the dual-channel optical interconnection component could transmit optical signals across the rotating interface. The maximum transmission rate can reach 2.14 Mb/s.

Keywords dynamic spatial interconnection, wireless infrared, rotary joint, transmission rate

1 Introduction

With the development of electrical communication technology, the conventional electrical interconnections have been replaced by optical interconnections. The optical interconnections are of high-bandwidth, high transmission rate, low noise, and immune to electromagnetic interference compared to the electrical interconnection [1]. The optical interconnections are classified based on the medium as fiber interconnection, waveguide interconnection, and free space interconnection [2]. The infrared technique belongs to the free space interconnection in the field of short-range signal transmission. The advantages of infrared techniques are its high security with high transmission rate and low cost. The half-duplex link is easily established between two transceivers in space, so a dynamic transmission link is constructed between the rotating infrared transceiver around the central axis and stationary transceiver utilizing these techniques. The optical signals will be transferred using this link between the rotational tracing system and the stationary controlling platform.

In this paper, the mathematical model of the dynamic optical interconnection between the stationary field and rotary field was constructed based on the infrared technology. A dynamic optical interconnection component was fabricated using this model and its performance was tested.

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JIA Dagong (✉), WANG Guanghui, ZHANG Yimo, ZHANG Yinxin, JING Wencai, ZHOU Ge
College of Precision Instrument and Opto-electronics Engineering, Tianjin University, Tianjin 300072, China
E-mail: Dagongjia@tju.edu.cn

2 Model of dynamic interconnection

Generally, most wireless infrared links are designed according to the directional line-of-sight (LOS) or hybrid LOS. The low path loss of these designs minimizes the transmitter power requirement and permits the use of a simple, low-cost receiver [3]. The interconnection model was constructed on the basis of the directed LOS. The wireless infrared transceiver is a key component in infrared communication. The package dimension and the way of radiation of transceivers are illustrated in Fig. 1. The transceivers consist of a transmitter offering the optical signals and a receiver that receives the transmitted optical signals. In this paper, the transceiver with an integral lens in a molded semispherical package employs a light-emitting-diode (LED) as the emitter and positive-intrinsic-negative (PIN) as the receiver. The diameter of the receiver lens is 2.0 mm and the diameter of the transmitter lens is 1.7 mm. The distance between the receiver center and the center of the transmitter is 5.65 mm. We suppose that the transmitter and the receiver are two points while designing dynamic interconnection, so the infrared transceiver can be simplified to a line with two dots (shown in Fig. 2). Because the LED source is viewed as a lambertian source [4], the optical intensities of the platform at d distance from the light source are the same. The packaged LEDs emit light into semiangles (at half power) ranging from about 10° to 30° in the transceiver, therefore, the emitting semiangle of the optical rotating field is initialized to 30° (see Fig. 1). Consequently, the shape of the emitting light is a cone with 60° vertex angle.

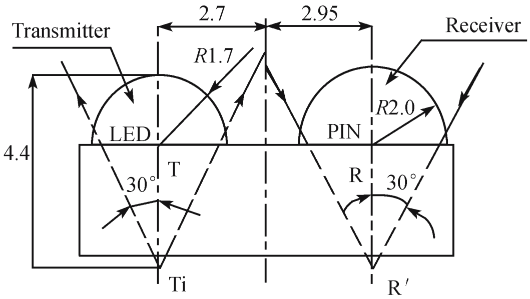

Fig. 1 Infrared transceivers package dimension and the way of radiation/mm

As shown in Fig. 2, one end is a rotary emitting field and the other end is a static-receiving field. In the dynamic optical interconnect model, the white points and letter *E*, represent the LED source, black points using letter *R* represent the PIN detector. According to the trace of the light source, we set four important locations along the circle: *A*, *B*, *C* and *D*. To ensure that each location can receive light, we find that *A* and *D* are two critical locations by analyzing the transmission theory. Based on the analysis above, the dynamic interconnection models are established in two different situations (Fig. 2(a) and (b)), when only end separation exists between the rotating field and the static field. If the radius of the optical field is *r* and the distance between the rotary field and stationary field is *d*, at the same time the light source rotate around axis *OO*', the relationship of the two fields can be described as follows

$$d_1 = \frac{2r}{\tan 30°} \tag{1}$$

$$d_2 = \frac{\sqrt{2}r}{\tan 30°} \tag{2}$$

Equations (1) and (2) show that the distance *d* is directly proportional to *r*. To ensure that emitting light of every location along the rotary field is received by PIN, the distance *d* should be equal to max (d_1, d_2).

Because the light radiation between the rotary field and stationary field can be affected by angular misalignment and lateral misalignment, the relative dynamic interconnection models are constructed in order to show the effect of two misalignments. Figure 3 shows the model of dynamic interconnection with angle misalignment. The influence of lateral misalignment is shown in Fig. 4. If θ is the angle between axis *OO*' and the axis of the receiving field, the angle between the center of the cone due to light radiation of the transmitter and axis *OO*' is $90° - \theta$. From Fig. 3, it can be seen that

$$\tan 30° = \frac{2r\cos\theta}{d - r\sin\theta} \tag{3}$$

From Eq. (3), the relationship between the two fields is described as

$$\cos\left(\frac{\pi}{6} - \theta\right) = \frac{d}{4r} \tag{4}$$

In Fig. 4 the model of the dynamic interconnection is shown, where the lateral offset is *L*, and the distance between the rotating field and stationary field is *d* too. We can obtain

$$L = \sqrt{d^2 \tan^2 30° - 4r^2} \tag{5}$$

Both analysis and calculations have been made under the assumption that one of the three affecting factors, end separation, angular misalignment, or lateral misalignment, exists during the transmission of optical signals. We can set the location of the two infrared transceivers by analyzing the dynamic interconnection models so that we can design the dynamic interconnection components using wireless infrared technology.

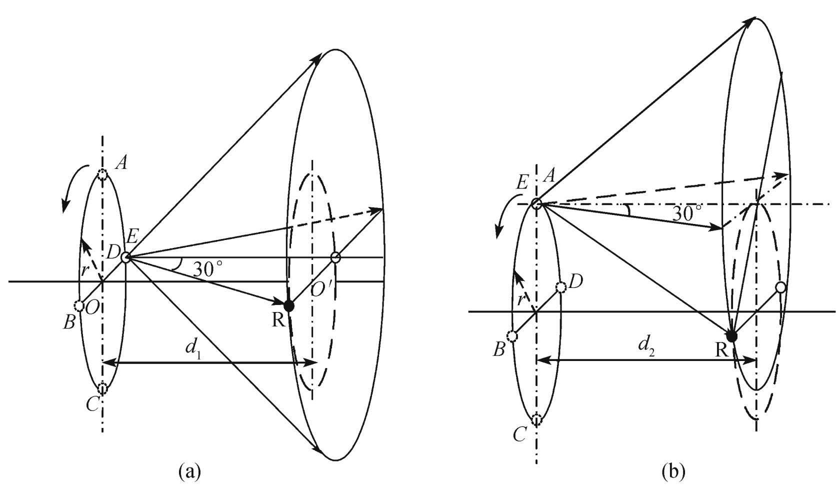

Fig. 2 Model of dynamic interconnection between rotating optical field and stationary field

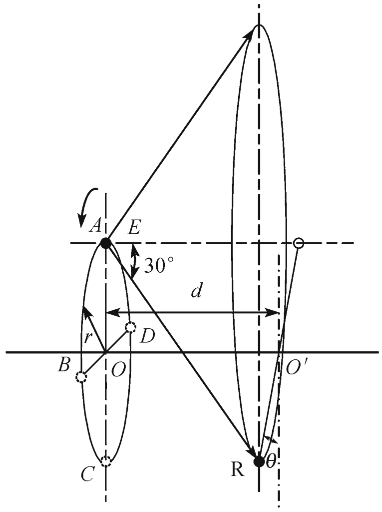

Fig. 3 Model of dynamic interconnection with angle misalignment

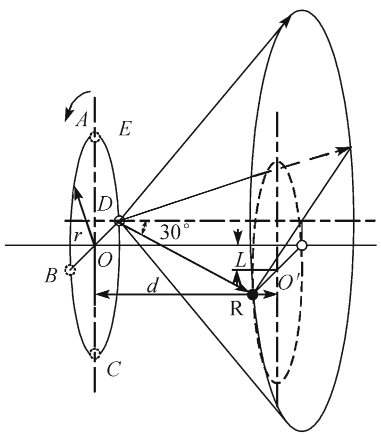

Fig. 4 Model of dynamic interconnection with lateral misalignment

3 Fabrication of dynamic optical interconnection component and data transmission experiments

Most conventional optical interconnection components were fabricated by using complex techniques including diffractive optics, refractive optics, and integrated optics [5]. However, the structure of these components is complicated and expensive. In order to transmit multi-channel optical signals, optical compensators are needed to couple light across the rotating interface [6,7]. The interconnection component designed using wireless infrared technique avoids employing a complex structure and optical compensators. Thus, this dynamic interconnection component is easy to fabricate with low costs. We design a dual-channel dynamic interconnection component based on the interconnection model constructed and calculating formulas. The structure of this component is shown in Fig. 5.

As shown in Fig. 5, the component mainly consists of two USB transmitting lines, an infrared transceiver A, the flange

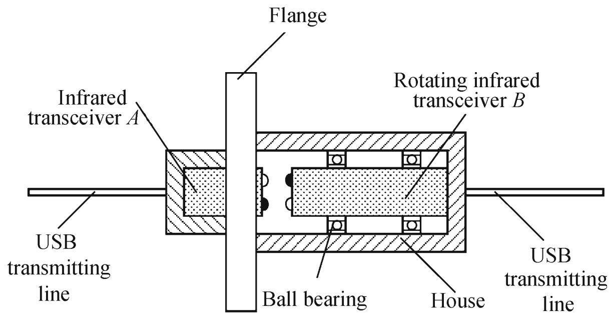

Fig. 5 The configuration of the dual-channel optical interconnection component

used to connect the exterior, a transceiver B rotating around the central axis, two ball bearings, and the corresponding house.

The radius of rotating field r is 2.82 mm according to the infrared transceiver's package dimension (see Fig. 2). In accordance with Eq. (1), the distance between the different transceivers $d = 9.8$ mm. As a result, $d = 9.8$ mm and $r = 2.82$ mm, the angular misalignment θ and lateral misalignment L is 0.32° and 0.45 mm according to Eqs. (4) and (5), respectively. By analyzing Eqs. (1), (4) and (5), we found that the value of θ and L will increase gradually as the value increases in d. The distance between the rotating field and stationary field is less than 1 m with limitation to the emitting distance of the wireless infrared transceiver [8]. Therefore, the maximum value of θ and L is 30° and 57.7 cm, respectively. In this paper, the parameters of the dual-channel interconnection component, that the distance is 50 mm, offset is less than 5 mm and tilt angle is less than 3° between the two transceivers, meet theoretical design requirements including $d = 50$ mm, $L = 28.4$ mm and $\theta = 30°$.

To test the feasibility of the multi-channel dynamic interconnection model, the transmission rate of the interconnection component is measured under the conditions of static state and rotary state where the IRMS6400 transceiver of 4 Mb/s data rate from Infineon Technologies [9] is employed. The experiments are done between two computers with different CPU frequencies under different operating systems. The first experiment is carried out between the two computers with the same processor frequency, where one computer runs on the Win 2000 operating system and the other runs on Win XP. The second experiment is done between the two computers under the same operating system, but one computer frequency is 2.8 GHz, while the other is 2.4 GHz. The experimental results are shown in Fig. 6.

The experimental results showed that the average data transmission rate of the dynamic interconnection component is 2.14 Mb/s from the computer with Win 2000 to that with Win XP. When the signal is transferred form Win XP to Win 2000, the average data transmission rate is 1.17 Mb/s. When the data is transferred from the computer with 2.4 GHz to the computer with 2.8 GHz, the average rate is 1.47 Mb/s. In the opposite direction, the average data transmission rate of the component is 2.04 Mb/s. The third experiment is done

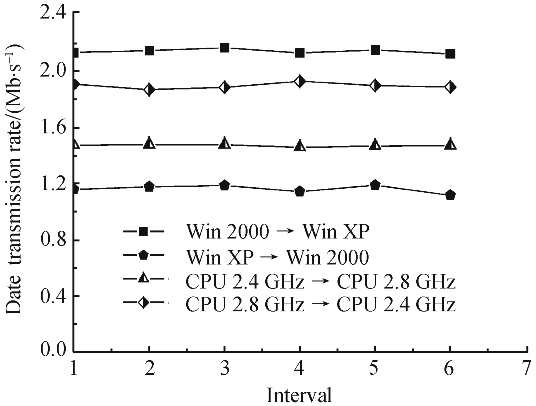

Fig. 6 Data transmission rate of optical interconnection component at different time

between the two infrared transceivers, which are similar to the transceiver used in the dynamic interconnection component. The experiment condition is also similar to the foregoing two experiments; that is to say, the computers used in this experiment are similar to those employed in the previous experiments. The data transmission rate of the infrared transceiver is about 2.16 Mb/s in the stationary state from the computer equipped with the transceiver with Win 2000 to the computer with Win XP. When the data is transmitted from Win XP to Win 2000, the data transmission rate is 1.21 Mb/s. While the computer frequency is modified according to the experimental requirement, the data transmission rates form 2.4 GHz to 2.8 GHz and from 2.8 GHz to 2.4 GHz are 2.08 Mb/s and 2.14 Mb/s, respectively. The experiment results indicate that the data transmission rate of the infrared transceiver in the stationary state is the same to the dynamic interconnection component. It supports indirectly the accuracy of the dynamic interconnection model.

4 Conclusion

The dynamic interconnection component as a critical component of transmission signals has wide applications in the fields of military, ocean, aviation, and industry. In this paper, incorporated with the wireless infrared techniques, a model of dynamic optical interconnection is constructed. Meanwhile, a dual-channel optical interconnection component is designed and fabricated based on the model and the data rate of this component is tested under two different conditions. Compared to the others, the component using infrared technique is simple and the cost is low. The experiment result shows that the data transmission rate of the designed component is more than 2.14 Mb/s and the minimum rate is 1.17 Mb/s. The experiment result has verified the accuracy of the constructed model.

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