Proceedings of the 11th
KACC, October 1996

REALIZATION OF SPATIALLY SEMI-OPEN SIGNAL FIELD AND ITS APPLICATION TO CAR GARAGING SUPPORT SYSTEM

°Shinji OHYAMA*, Kouji IHARA**, Li CAO* and Akira KOBAYASHI*

*Dept. of Control and System Eng., Tokyo Institute of Technology, Meguro-ku, Tokyo 152, JAPAN
Tel: +81-3-5734-2325; Fax: +81-3-5734-2553; E-mail: sohyama@ctrl.titech.ac.jp
**Personal & Mobile Comun. Comp. Development Dept., Sony Corp., Minato-ku, Tokyo 108, JAPAN
Tel: +81-3-3458-7606; Fax: +81-3-3458-7489; E-mail: k-ihara@me.sony.co.jp

Abstract This study proposes a "spatially semi-open signal field" which aims at the measurement of an automobile's position and attitude in a semi-open field such as a car garage. The basic characteristics of this signal field was applied to a "car garaging support system." This study is based on the concept of a "signal field."

Keywords Signal field, Local positioning system, Position measurement, Car garaging, Parking space

1. INTRODUCTION

There are various types of demands for position measurement in a restricted environment. For example, the distance measurement between a material object and a robot hand, the alignment of a mask and wafer during the LSI process, and the position sensing of an automated vehicle in a factory. In these cases, it is important to measure the relative position with a precision appropriate to the scale of the field considered.

This paper deals with an example of such position measurement regarding a car garaging system using a new type of signal field[1, 2]. A new concept for an **LPS** (Local Positioning System) was proposed in a previous paper[3], which is our term for a position measurement system in a limited area, in contrast to a GPS (Global Positioning System). The problem described in this paper is also an example of LPS. A specific signal field named "spatially semi-open signal field" is proposed and its application is mentioned in the following section.

2. REALIZATION OF SPATIALLY SEMI-OPEN SIGNAL FIELD

Fig. 1 is a schematic view of this system. Two light sources (A and B) are arranged on one latus of the parking space, and each of them is driven by a sine wave with a specific amplitude and initial phase shift, that is, their lighting functions are as follows:

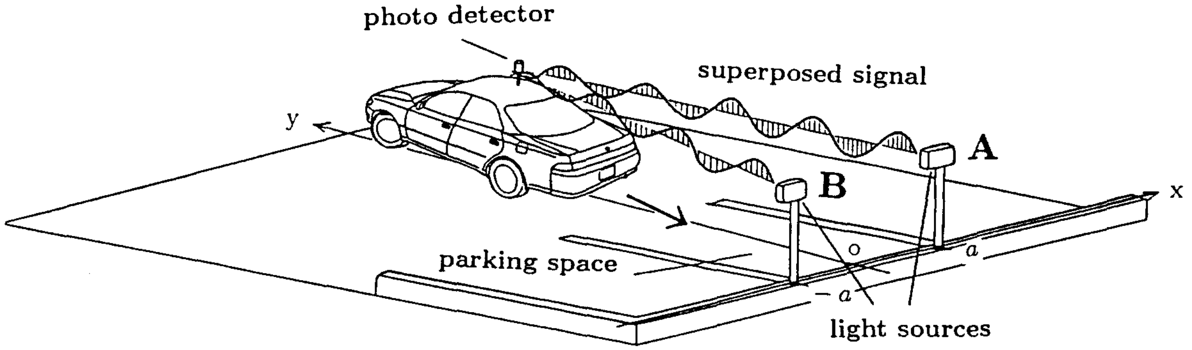


Fig. 1. Schematic view of car parking system: arrangement of light sources and detector.

$$A : A(t) = \kappa_A \cos(\omega t + \theta), \quad (1)$$

$$B : B(t) = \kappa_B \sin \omega t. \quad (2)$$

A specific signal field is generated by the superposition of both signals in the parking space. This is the spatially semi-open signal field; only the front side area of the two light sources can be utilized, not the back side. When the signal $P(t; x, y)$ is obtained at any position $P(x, y)$ of a photo detector with non-directional sensitivity, $P(t)$ is given by

$$P(t) = \frac{\kappa_A \cos(\omega t + \theta)}{(a-x)^2 + y^2} + \frac{\kappa_B \sin \omega t}{(a+x)^2 + y^2} = A \sin(\omega t + \phi). \quad (3)$$

In eq.(3), A and ϕ are expressed as the next equations, respectively.

$$A = \sqrt{\left(\frac{\kappa_B}{(a+x)^2 + y^2} - \frac{\kappa_A \sin\theta}{(a-x)^2 + y^2}\right)^2 + \left(\frac{\kappa_A \cos\theta}{(a-x)^2 + y^2}\right)^2} \quad (4)$$

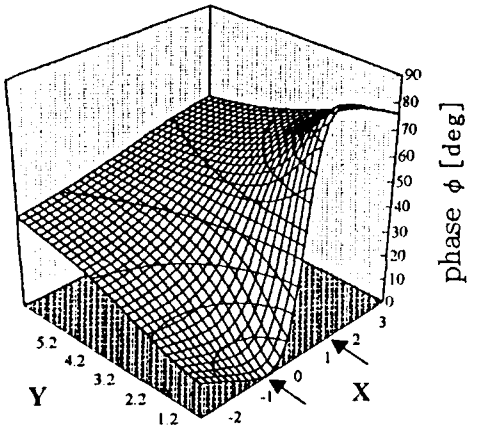
$$\phi = \tan^{-1}\left(\frac{\frac{\kappa_A \cos\theta}{(a-x)^2+y^2}}{\frac{\kappa_B}{(a+x)^2+y^2} - \frac{\kappa_A \sin\theta}{(a-x)^2+y^2}}\right) \quad (5)$$

In these equations, a is determined by the size of the garage, while both the initial phase θ and the luminance ratio $(= \frac{\kappa_A}{\kappa_B})$ are the variables capable of being adjusted, and we can precisely control them.

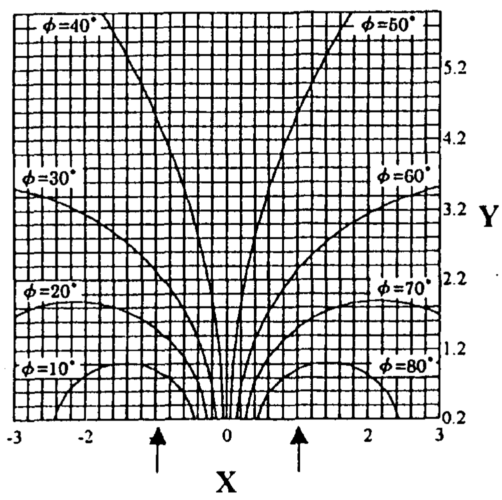
3. CHARACTERISTICS OF THE SEMI-OPEN SIGNAL FIELD

Fig. 2 shows the distribution of the phase shift and equi-phase lines based on eq.(5). In these figures, the position of the two arrows indicates the sites of the two light sources.

Equi-phase lines are spread radially from the center of the two light sources. This fact means that one of the suitable equi-phase lines can be used as an induction curve for a car in order to lead it to the final position. In addition, the distribution of equi-phase lines can be changed by adjusting the luminance ratio of the two light sources and/or initial phase of the lighting function, and the form itself of the equi-phase lines can also be intentionally controlled by adopting either point light sources or line light sources or the combination of both.



(a) Distribution of phase shift ϕ.



(b) Equi-phase lines of phase shift ϕ.

Fig. 2. Characteristic of semi-open signal field.

Consequently, when the detector catches the composed signal, and the phase shift is measured, the car is able to reach the end so that the measured phase is equal to a set value.

4. EXPERIMENTAL

Fig. 3 shows a schematic view of the experimental system. In these experiments, non-directional light sources were prepared by arranging some devices with directional sensitivity to match the mentioned theory. To be specific, 12 infra-red LEDs are radially arranged on the base material as shown in **Fig. 4**. A non-directional photo sensor is also made by arranging 6 photo diodes attached to the side surface of a hexagonal prism as shown in **Fig. 5**.

LED arrays A and B are driven by a sine wave de-

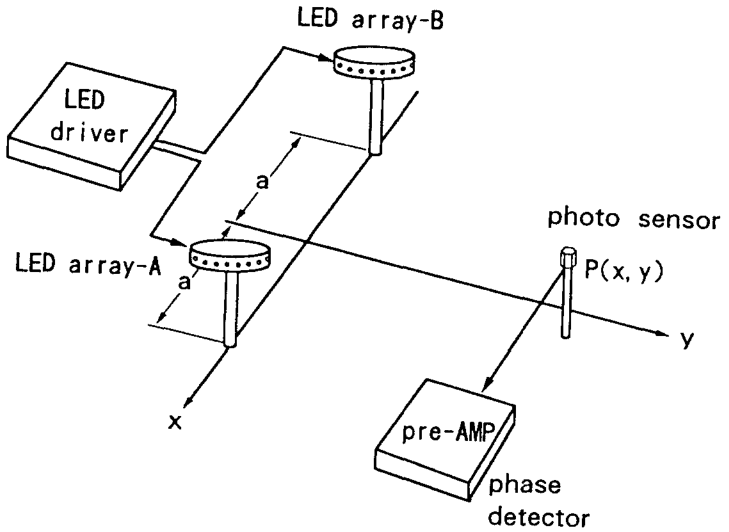


Fig. 3. Schematic view of experimental setup.

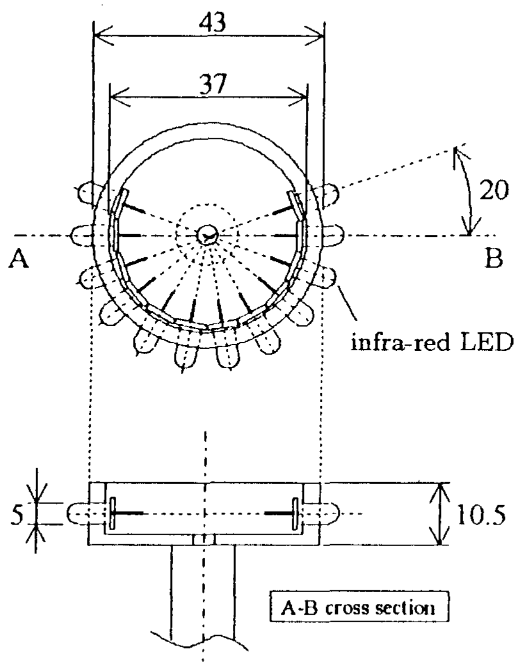


Fig. 4. Structure of light source.

scribed in eqs. (1) and (2). The lighting functions are derived from a function generator, and both the luminance ratio ($\frac{\kappa_A}{\kappa_B}$) and initial phase shift θ are set by the LED driver. The optically superposed signal is detected by the photo sensor composed with 6 photo diodes; a small signal from each diode are summed and amplified, and its phase shift is measured by a lock-in-amplifier.

Fig. 6 shows an example of the experimental results of the measured phase shift ϕ. Compared to a Fig. 2, the tendency of the graph is coincident, but a distortion

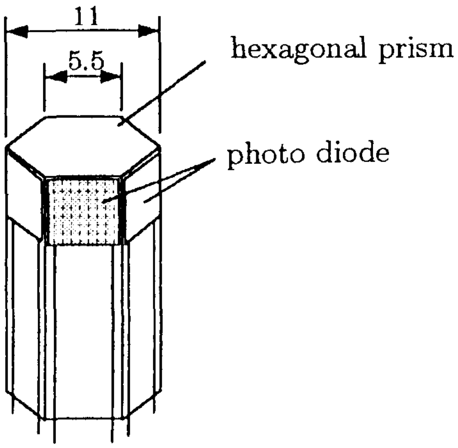
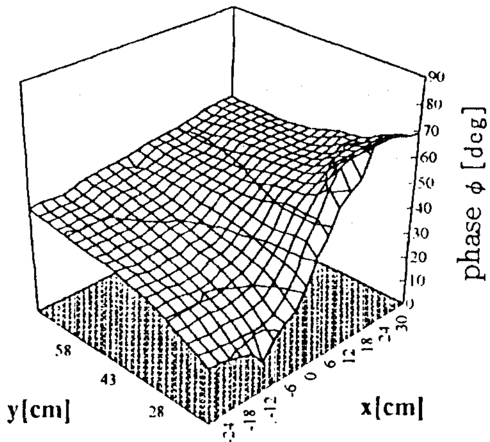


Fig. 5. Structure of photo sensor.

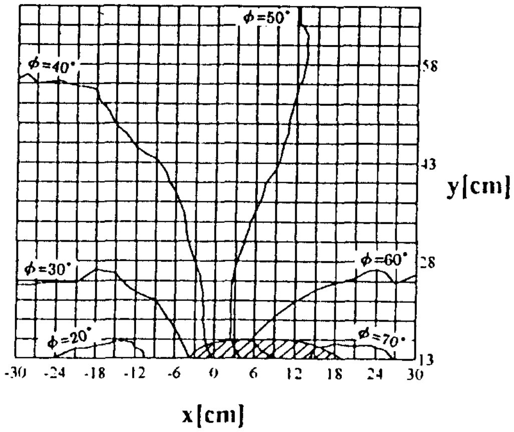
of the equiphase lines was observed.

The effects of changing the ratio of brightness and the initial phase were also experimentally confirmed.

The dispersion of every LED device is considered to



(a) Distribution of phase shift ϕ.



(b) Equi-phase lines of phase shift ϕ.

Fig. 6. Experimental results.

be the cause of the difference from the non-directional characteristics of the LED arrays. Developments of new non-directional light sources are for a future study.

5. CAR GARAGING SUPPORT SYSTEM

This paper also deals with a car garaging support system using this signal field. In Fig.1, although only single photo detector is set on the car, two sensors are required to lead a car to a garage along an induction curve. That is, two photo sensors are necessary on the roof of a car ahead and behind at different height in addition to Fig.1.

As previously described, one suitable equi-phase line is selected, which was tuned for the induction curve by adjusting both the luminance ratio and the initial phase shift. We call it the induction curve ϕ_0. The car moves along this induction curve to the end of the car space. In order to catch the curve, its steering wheel is controlled so that the phase difference of one sensor is equal to the other. The stopping position is determined by the amplitude of a sensor's signal.

To utilize this procedure, both the sensing part and the LED control part must have the same information of measured position. To measure the phase shift ϕ, a common clock signal is also needed. Then, it is important to communicate the clock signal and the position information to each other.

6. CONCLUSIONS

A new spatially semi-open signal field is proposed and its characteristics were investigated. Its equi-phase lines are suitable for an induction line after the luminance ratio and the initial phase shift of the lighting function were adjusted. Not only did we propose the idea of this signal field, but also examined its characteristics by constructing the prototype measurement system. Finally, we proposed a car garaging support system using this signal field.

REFERENCES

[1] A.Kobayashi and S.Ohyama, "Fundamental study on optical rotating field," Trans. of Society of Instrumentation and Control Engineers in Japan, **Vol.21**, No.11, pp.1202–1209, 1986 (in Japanese).

[2] S.Ohyama, Y.Tanaka and A.Kobayashi, "Realization of enclosed signal field by linear LED's and its application for position measurement," *Technical digest of the 11th Sensor Symposium,* pp.51–54, Tokyo, 1991.

[3] S.Ohyama and A.Kobayashi, "Local positioning system by means of enclosing signal field," *Digest of technical papers of Transducers '95,* **Vol.1**, pp.115–118, Stockholm, 1995.