Innovative Technique for Meeting Laser Tracking Criteria at Near and Far Ranges

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Nahla A. AL Jabbar
Ministry of science & Technology / Baghdad.
Email: hushamabid@yahoo.com
Dr. Hisham A. Maliek
Ministry of Science & Technology/, Baghdad.
Dhafir Aziz Dhadir
Ministry of Science & Technology /Baghdad.

Abstract

Designing **L**aser **D**etection and **T**racking **S**ystem (LDTS) needs meeting some certain requirements, one of these requirements is meeting tracking criteria for quadrant photodetector (QPD) at near and far detection range for the target in question through simulating these requirements. A reflecting truncated tetrahedral prism technique design and four separate photodetectors of certain shapes are introduced as a method to avoid tracking failure case.

Keywords: Laser, Detection, Tracking, FOV, QPD

تقنية مبتكرة لموائمة معايير التتبع الليزري عند المديات القريبة و البعيدة

الخلاصة

يحتاج تصميم منظومة الكشف و التتبع الليزري الى توفير متطلبات محددة, احد تلك المتطلبات هو مؤائمة معايير التتبع للكاشف الرباعي عند المدى القريب و البعيد للكشف عن الهدف قيد الدراسة من خلال المحاكاة لتلك المتطلبات . تم ادخال تقنية الموشور الرباعي الناقص العاكس مع اربعة كواشف ذات اشكال محددة كطريقة لتفادي حالة فشل التتبع.

الكلمات المفتاحية: ليزر ،كشف, تتبع, مجال الرؤية, الكاشف الرباعي

INTRODUCTION

The use of optical systems for tracking is becoming a progressed and advanced technique during the last four decades. The newly developed system comes in variety of sizes, shapes, and capabilities. The input data of the target's position requires a system of continuously estimating its present value, such a system is called tracking system. Tracking system is concerned with the execution of accurate movements at the correct time [1]. The task of this unit is to track or follow the target and to generate information about the target position that fed to control unit [2]. The tracking system may be employed to measure the target position by using radar or optical source. A laser beam is used as an illuminating optical source. At present, quadrant photodetectors ,QPDs, are widely used as optical sensors to measure the

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

angular position of a moving target in a pulse laser tracking system [3] .The QPD consists of four photodiodes (2 X 2 array), which are electrically isolated from each other by a distance and positioned symmetrically around the axis of the QPD. Target image spot size is the core of tracking criteria. Tracking criteria play a key role in receiving unit design for remote LDTS.

LDTS's Performance

LDTS performance is affected by detection and tracking processes tracking process is affected by no. of factor like: LDTS's field of view which is usually expressed as an angular area viewed by the system and denoted as FOV, tracking criteria and minimum tracking range [4].Minimizing FOV implies to minimize back ground noise, securing detecting and tracking a single target. Minimizing FOV could be achieved by minimizing QPD's area, hence its diameter. This will lead to enlarged receiving lens diameter [5], hence long focal length [6], for given F – number, F#. This approach will lead to imply large image spot size [7].

In case of target image spot size larger than QPD's active area, a tracking failure may take place, because there is violation to tracking criteria which are [8], (See Figure (1)):

(1) Target image spot radius, $\mathbf{R_s}$, should be smaller than QPD’s radius, $\mathbf{R_d}$, by amount specified by optimum radius for tracking, $\mathbf{R_{opt}}$, of tracking mode zone which is given as:

$$R_{opt} = \frac{R_d}{2\sqrt{2}} \quad \text{.... (1)}$$

(2) Target image spot radius, $\mathbf{R_s}$, should be larger than metallurgical separation **2a** between each two segments of QPD, which specifies minimum radius for tracking, $\mathbf{r_{min}}$ which is given as:

$$r_{min} = a\sqrt{2} \quad \text{.... (2)}$$

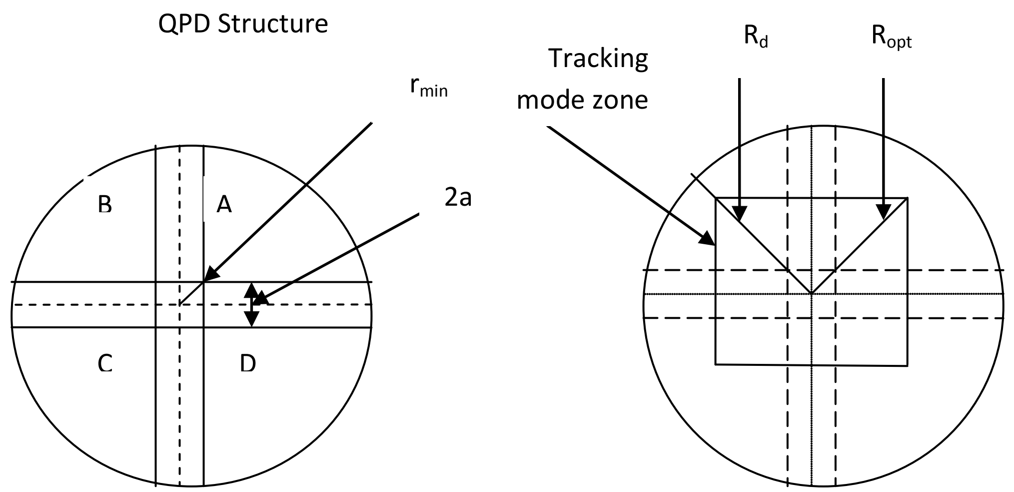

Figure (1) shows (a) structure of QPD, r_{min}, including metallurgical separation between each two segments and (b) tracking mode zone.

Reflecting Truncated Tetrahedral Prism Technique

This technique is to avoid tracking failure during tracking mode which uses truncated tetrahedral prism. This technique offers the following:

(i) Using truncated tetrahedral prism, its surfaces are coated by highly reflecting material such as silver, in front of QPD which will be denoted as basic QPD. The central part of the prism, the top, which will be denoted as (1) omits the fallen rays to basic QPD, but side planes (2-5) reflect it onto four photodetectors which will be denoted as terminal QPD, serving as four basements of new equivalent QPD [9].

(ii) At small size of target image spot, LDTS operates basic QPD, and the terminal QPD will be off.

(iii) When target image spot size exceeds the admissible, namely area of basic QPD, the terminal QPD is operated and turns off the basic QPD.

(iv) Each photodetector of the terminal QPD is connected to separate amplifier and comparator which are separated from those of basic QPD.

(v) The terminal QPD is made of the same material, structure, and AR coating as that for basic QPD, except the area and shape.

Once, to find out dimensions (area) and shape of each photodetector of the terminal, it should be to calculate dimensions and shape of access target spot that implies tracking failure.

Let Y_1 be on fourth basic QPD circumference, see Figure (2), which is given as:

$Y_1 = 2\,\pi\,Rd/4$ (1)

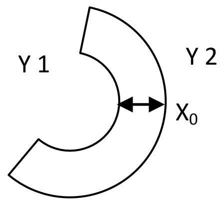

Figure (2) illustrates target image spot circumference for one segment compared to QPD segment circumference.

Let Y_2 be one fourth target image spot circumference which is given as:

$Y_2 = 2\,\pi\,R\,s/4$ … (2)

Distance between Y_1, Y_2 is X_o which represents the major dimension of image spot which is given as:

$Xo = Rs - Rd$ …(3)

For $Rs > X_o$ then $Y_2 > Y_1$, so Y_2 will be the major dimension of access target image spot, target access image spot has meniscus shape.

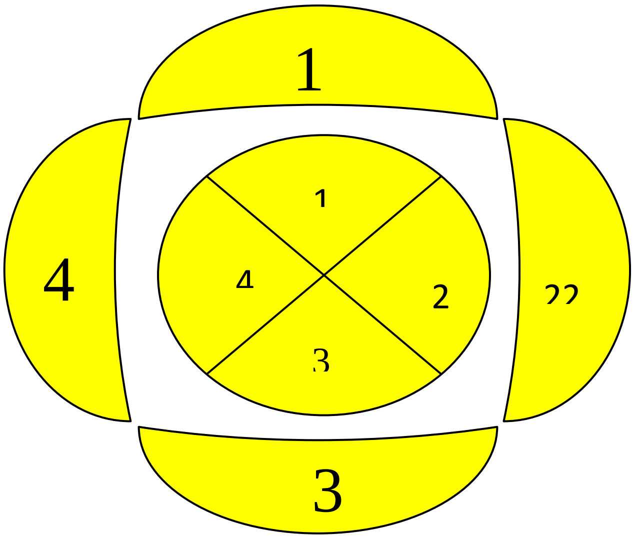

Figure (3) shape and configuration of the Photodetector, the basic and terminals. Innovative Technique for Meeting Laser Tracking Criteria at Near and Far Ranges.

(vi) Load resistance, $R_{L,}$ connected to each photodetector of terminal one should be chosen carefully, so that:

– It keeps response time of each photodetector within the period of half pulse width (duration) to maintain detecting the same repetition rate of transmitted signal.
– It keeps S / N approximately the same as that for basic QPD. This Technique is illustrated in Figure (4).

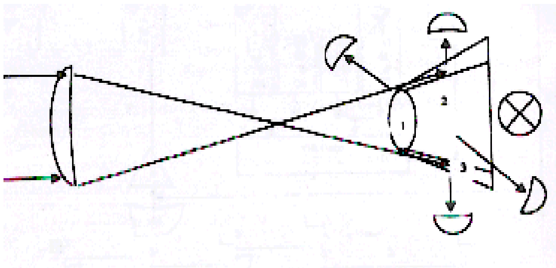

Figure (4) illustrates truncated tetrahedral prism technique.

– Electronics of this technique is illustrated in figure (5).

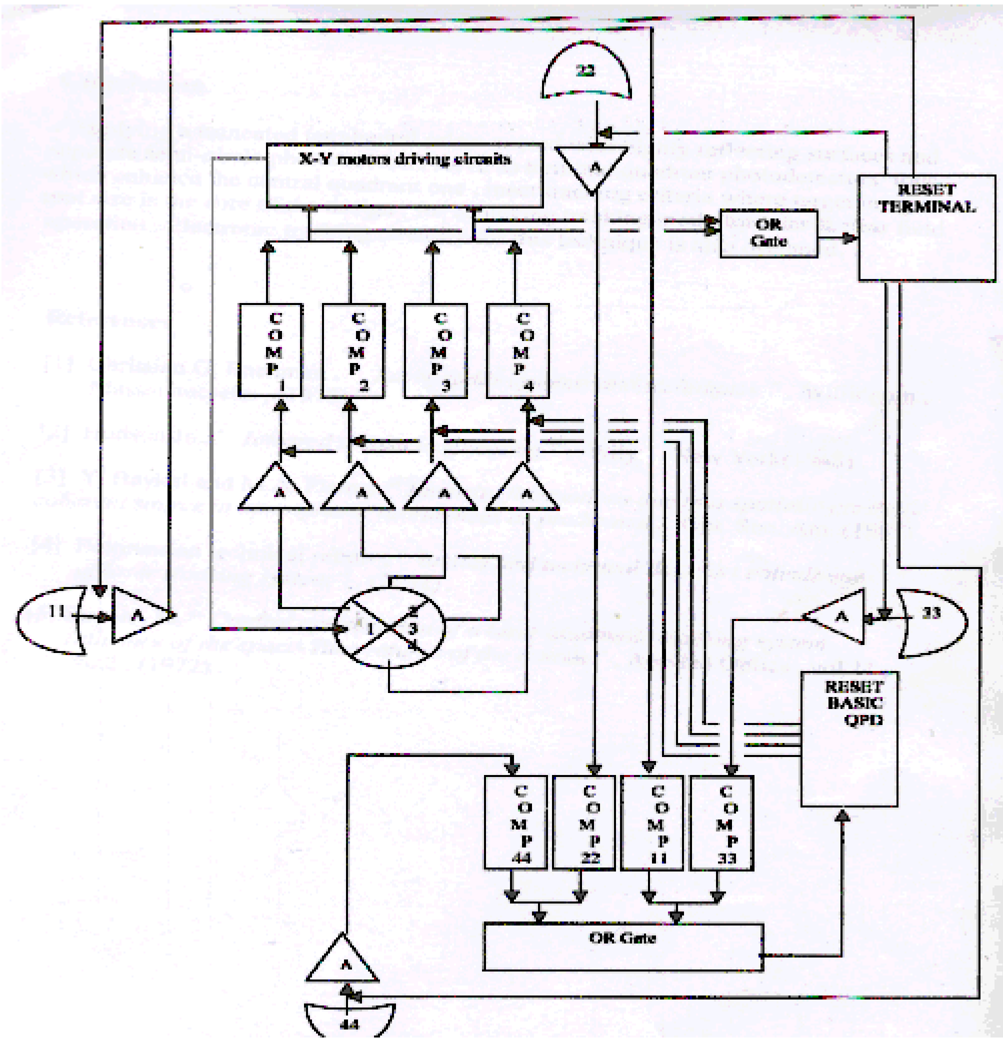

Figure (5) Illustration tracking electronics for far and near ranges.

Conclusion

Applying a reflecting truncated tetrahedral prism coated with highly reflecting surfaces and four separate meniscus photodetectors serve as terminal QPDs, for far target detection, which enhance the central quadrant one. This technique meets requirements of tracking criteria where target image spot size is the core of the design, for achieving tracking mode for far & near field operation. Electronic tracking circuitry for this technique is also designed.

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