A new advanced design and implementation of laser warning system

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***Abstract*— Nowadays there are a huge progress in the Electro-optical System and the Laser weapon, not only were danger of laser weapons on the war but also civilian target. The laser warning receiver system can detect, classify, identify and give warning of the hostel laser threat aiming in a very short time with high sensitivity and it can activate the electro-optical counter measurement system, directly or with the user. In this paper we do a design and implementation for laser warning system circuit, the new purpose circuit increase the performance of the warning system and increase the detection field of view.**

Keywords—Amplifier; detection head; decoding board; laser warning;

I. INTRODUCTION

There are a lot of attacks on civilian places, laser warring receive systems are plays an important role to give alarm about the threat. The laser warning system, can detect the incoming laser threat signal and warning it on the real time. The system can judge the threat type (laser range finder) LRF [1], (laser target designator) LTD beam riding, (illuminator laser) IR code generally is based on fixed frequency. As for the laser threat type judgment laser pulses transmitted from LRF shall be in small width and low (pulse repetition frequency) PRF [2], while the beam transmitted from LTD is similar to LRF pulse. This design is more high speed and more responsively, the false alarm rate is very small and so covers a big FOV to increase the probability of detection comparing with others system [3].

In this paper the amplifier board and acquisition board was made by using high speed, low noise, and low distortion, more stable component like (ADA4817, AD603, AD8056AM, AD8055ART, and ADCMP600). Killer laser weapon shall usually as (continuous wave) CW laser or wide pulse laser in extreme energy density; all these characteristics shall be the basis for threat type judgment [4]. We need to improve their threshold detection level and false alarm rate for detection of low intensity pulsed lasers associated with beam riding type guided missiles. This is not the only part to look after in orders to enhance laser warring sensor detection capability.

Most of conflict areas in the modern world have hot climates area such as the Africa have severe weather conditions which are now know to affect the performance of laser warring system negativity. For example every eight degrees increase in temperature doubles the noise that make a big problem to the performance of any laser sensor [5]. There are many types of laser threats; table 1.1 summarizes these different types of laser threats.

This paper organized in four sections, the second section illustrates the design steps and analysis of the LRF and the third section discusses the simulation and results and the last section shows the conclusion of the paper.

TABLE 1.1 LASER THRETS

Laser Types / Specification	LRF	LTD	Laser beam riding missile	Laser weapons/ Blinder	Lidar
PRF	Single pulse up to 8HZ	8Hz to 40 HZ	...KHZ	Up to 30 HZ	5 KHZ to 150 KHZ
Wavelength	904nm,1.54nm	1.064µm	904nm-1.06µm	0-532µm	0.47-0.532µm
Advantage	High power, small divergence	• Even higher power, small divergence. • Warning time (5-20sec). • Pulse trains make simultaneous engagement for multiple targets possible.	Difficult to detect and jam	• Threat to human eye. • Threat to Eo systems.	- high level of accuracy - ability to cover large areas quickly - quicker turnaround, less labor intensive, and lower costs than photogrammetric methods
Use	User laser time of flight and reflectance to operate	Desginate the target before attack	Illuminate the target during attack	Dazzler the TV sensor and human eyes	Navel -submarines

II. DESIGN AND ANALYSIS OF THE LWS

The new design and construction depends on simple and cheap components to reduce the cost and at the same time using the high speed electronic component achieving a high performance. The laser warring receiver model achieves the best amplification factor and the band width of amplifying channels with help of concrete parameters of trance impedance amplifier and subsequent cascades [6]. That is new model for LWS, it is consists of; Laser warring head, Processing unit, Indicator unit, we will discuss these components in details.

A. Laser warring unit

It is consists of detection head, 28 detecting heads of warring unit are installed in a shell and distributed in the circle shape by two row up and down and 14 detectors on the top and digital compose as shown in fig. 1 and fig. 2.

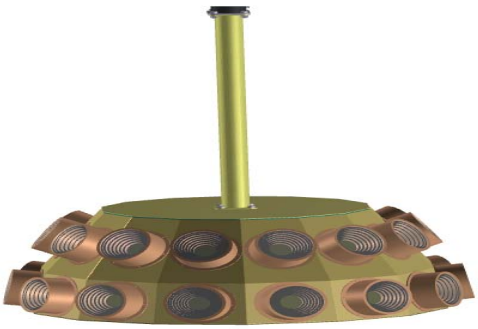

Fig. 1 warning detection heads

Fig. 2 LWR unit

B. Detection head

The detection head consists of lens, detector amplifier board, acquisition board, four quadrant detectors on detection head shall connected with amplifier and acquisition board, fig. 3 shows the detection head [7].

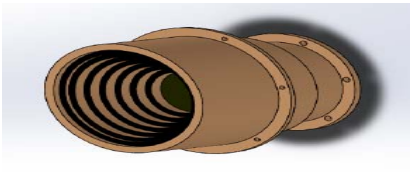

Fig. 3The detection head

If any detection head detects laser radiation signal, it should be convert the optical signal into electrical signal and send it to the amplification PCB for signal amplification [8].

If the signal exceeds the preset threshold the pre-processing PCB in the warning unit must be transmit signal to control data acquisition PCB to acquire and read data transmit angle data as shown in fig.4.

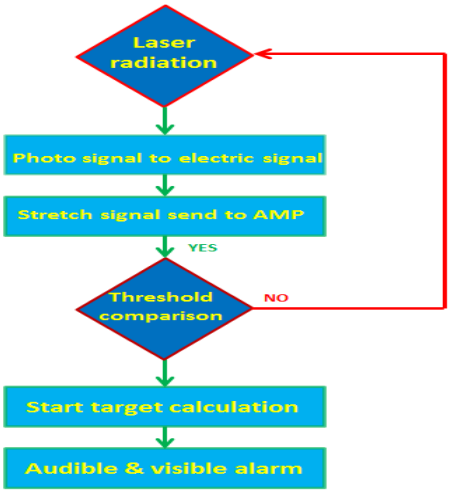

Fig. 4 Work flow for detection threat

The encoding and decoding PCB must be decode the laser synchronization signal transmitted from the pre-processing PCB and judge threat type depending on the arrived laser radiation pulse signal. After the laser data message is sent from warning unit to processing unit and the north direction sent from digital compass to processing unit to make the calculation to get the real direction for threat as shown in fig.5.

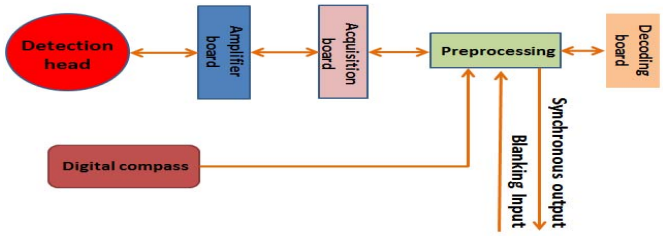

Fig. 5 Electrical component block diagram

IF there is any laser detected must be convert the optical signal into electrical signal which shall be then sent to the pulse width spreading circuit for peak value storage after being processed, if the signal exceeds the threshold, the threshold comparison circuit shall be sent out laser synchronization signal to decoding board and to identifies encoding mode and pulse width and pre-processing board to complete data reading storage and transmission and calculate angle of data packet according to characters of radiation signal as shown in fig.6.

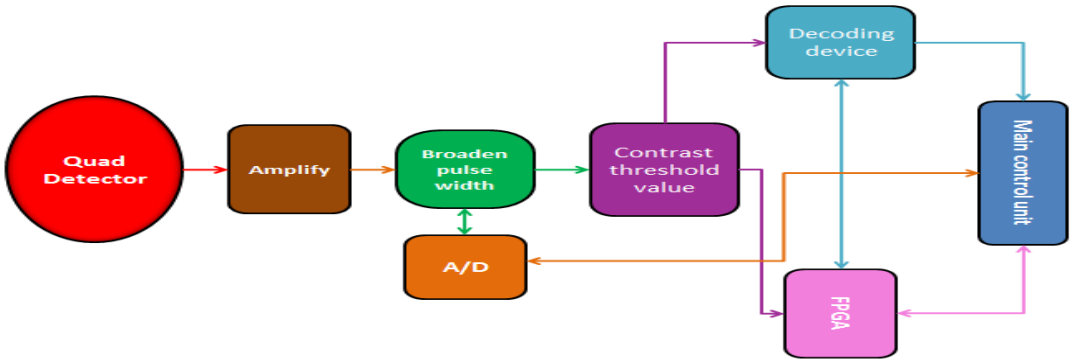

Fig. 6 working principle of laser warning detector

The amplification and acquisition boards are design for photoelectric conversion for laser radiation signal, to amplification and acquisition of weak signal. The pulsed radiation signal converted to weak current signal through a four quadrant detector and then it's converted into voltage signal by pre-amplifier which shall be amplified above 100mv by the amplification circuit as shown in fig.7.

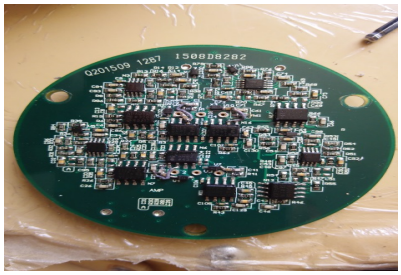

Fig. 7 Amplifier board

The gain of amplification circuit and reference level of comparator shall controlled by signal processor. They can be adjusted with in specific range depending on back ground noise and signal magnitude to increase the system dynamic range. Four signal send to comparator then send to FBGA in the same time amplification signal will be send to the signal to pulse width spread, which should be sent to the other four comparator shall send signal to FPGA [10].

After comparison 8 channel of pulse in FPGA and make some filtration and correlation processing in FPGA and then be send to pre-processing PCB which shall sent data acquisition control signal to the signal process to control AD start data acquisition as shown in fig.8.

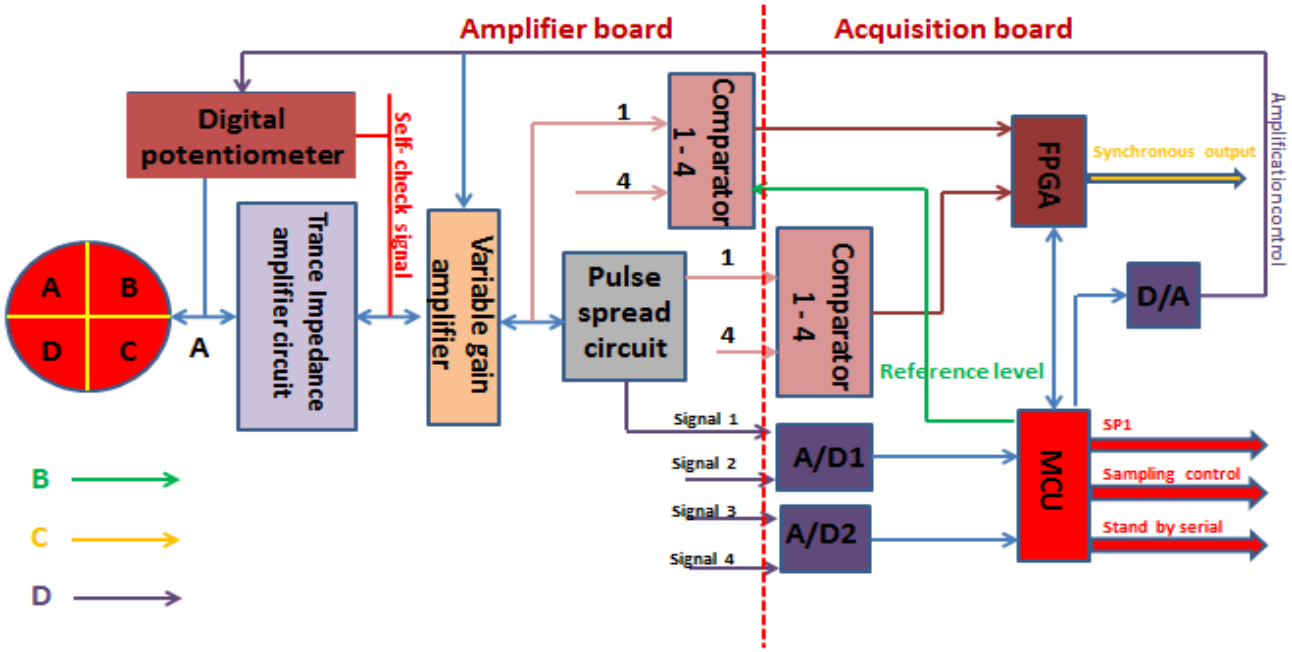

Fig. 8Block diagram of amplifier and collecting board

III. SIMULATION AND RESULTS

A. Pre-processing

Reduce digital signal of amplitude from acquisition board at the head of detector to complete storage and filter of data synchronization signal were sent by acquisition board were used to identify the false alarm. Receive the blackout signal and reduce the false alarm as shown in fig.9

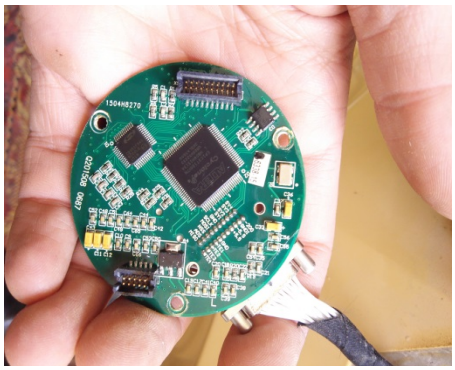

Fig. 9 preprocessing board

Pre-processing have arithmetic unit to complete angle calculating and information change with main control unit (signal processor) Pre-processing has a function of decoding.

B. Main control PCB

Receive blanking signal from the main control unit. Perform false alarm judgment and sync signal from data acquisition PCB and sent out laser synchronization signal. Receive the digitized signal of each magnitude signal channel from the detection head and perform data and filtration.

C. Decoding board

First we must record the arrival moment of laser pulse, then we can calculate the time intervals between pulses, and then we compare time intervals such as the equal time intervals for PRF, and unequal time intervals for LTD, finally it is ready for calculating the PRF for LRF in the case of constant time intervals.

The data was extracted from LWS, it is the most important parameter, Because it help us to know the hostile laser code. Code was extracting help us to identify the kind of laser threats. Known the laser code help us to take the true decision and so known the seeker code, because laser designator and seeker use the same pulse coding system to ensure that a specific seeker and designator combination work in harmony. In the final the seeker will trace the energy with correct coding. Figure 10 illustrate there in no laser threat detect that is the normal case. When the laser warning system received laser threat, after processing laser threat we can laser pulse in fig 11. After more analysis we can get laser threat code clearly as shown in fig 12.

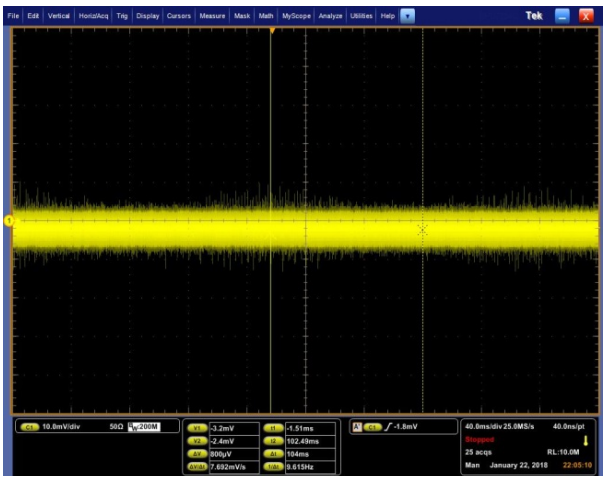

Fig. 10 No laser threat

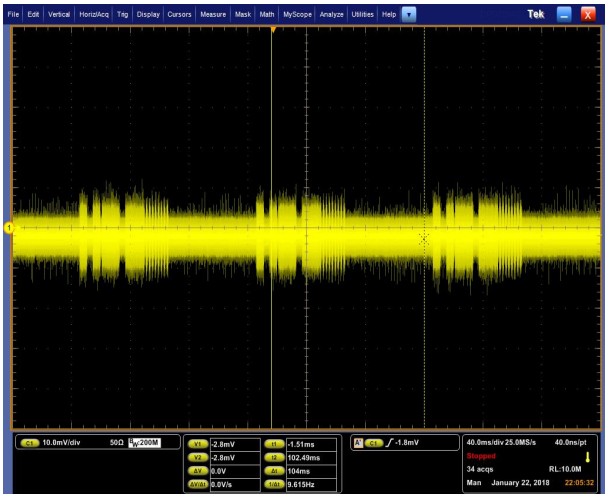

Fig. 11 Laser threat detected

Fig. 12 laser code analysis

The quadrant detector was 3mm In GA As quadrant detector, the In GA As detector as shown in fig.13 and fig.14 provided greater sensitivity over germanium quadrant detector used earlier in the development of quadrant detector. The quad cell was operating in photoconductive mode because it use in high speed and more responsively application, but the main problem here the dark current so should be use dynamic threshold and provide a constant if the quad cell was AC coupled to trans impedance amplifier rejecting the DC back ground.

Fig. 13 Front of Quad detector

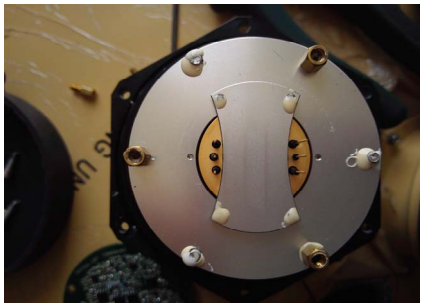

Fig. 14 Back of Quad detector

The Ac coupling increase the dynamic rang of the front amplifier. The trance impedance amplifier provides the first stage of signal amplification and filtering ,the second stage was a variable gain amplifier (VGC) used to provided automatic gain control (AGC) for the quad cell circuit the control voltage provided by the DSP.

The Quad cell detector noise Analysis was completed to determine circuit design that would provide the phase locked loop required 0.4 SNR for Improvement the detection and an optical Quad of 0.67 dBm. The Trans impedance Amplifier circuit designed was very sensitive of Quad cell .the circuit by using ADA4817.

The Trans impedance amplifier circuit requires a feedback capacitor (cf) in parallel with the feedback resistor to maintain stability by compensating for parasitic capacitances at inverting node amplifier in fig.15.

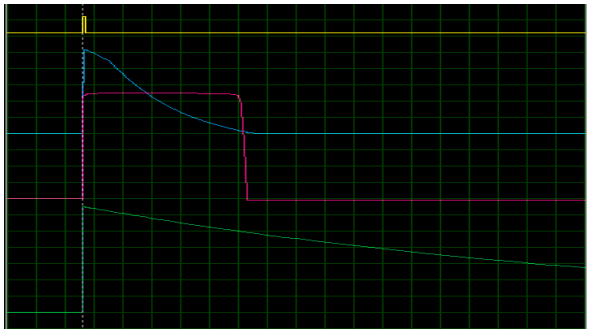

Fig. 15 Stable stretch and amplification signal

When you built your design must be built your circuit at first then you can choose your op-amp, to achieve the performance you need. Because if you do the opposite you couldn't achieve what you need, for example in our design better approach would be determine the largest feedback capacitor allowable in circuit and then select the op-amp with sufficient gain band width to be stable with feedback capacitor the oscillation happen when the op-amp gain band width not stable with feedback capacitance as in fig.16.

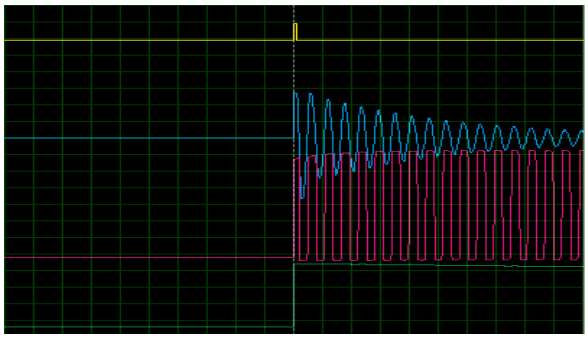

Fig. 16Unstable stretch and amplification signal

But should be take on our thinking, there are the difference between the normal detector used on the land platform and the air platform that had been put on the plane. The detector working as a missile Approaching warning system (UV detector), the operation distance of UV detector is short (about 2-3Km), The UV detector is mainly used for the high maneuvering platform such as airplane not applicable for vehicle plate form.

The benefit to use two lines of detector with different angles, because the vertical FOV of each individual optical window being 60°, it is unable to cover the big range of -5°~70°. In elevation, so in our design arrange two lines of detectors to make it.

According to which basis we judge the type of threat, the approaching threat type shall be classified according to receiver laser pulse periodic characteristics, and the LRF shall base on repeated frequency pulse while the laser illuminator shall be based on encoding pulse.

The Trans impedance amplifier circuit consists of photo diode, amplifier, and feedback capacitor resistor. How to design stable Trans impedance amplifier for automatic, the reliability of the detected signal depends on a large degree upon the accuracy and stability of detection circuit, a key element of that circuit is Tran's impedance amplifier (TIA), which charge a low level photo diode current signal to a usable voltage output as shown in fig.17 which illustrate design circuit to amplifier, acquisition and processing boards.

To increase the performance of warning systems, The key to probability of detection and false alarm rate signal to clutter ratio and signal to noise ratio, local back ground that means as well as the variation in the back ground and the target intensity.

In any design, for warning receiver there important parameters like targets parameters, environment parameters.

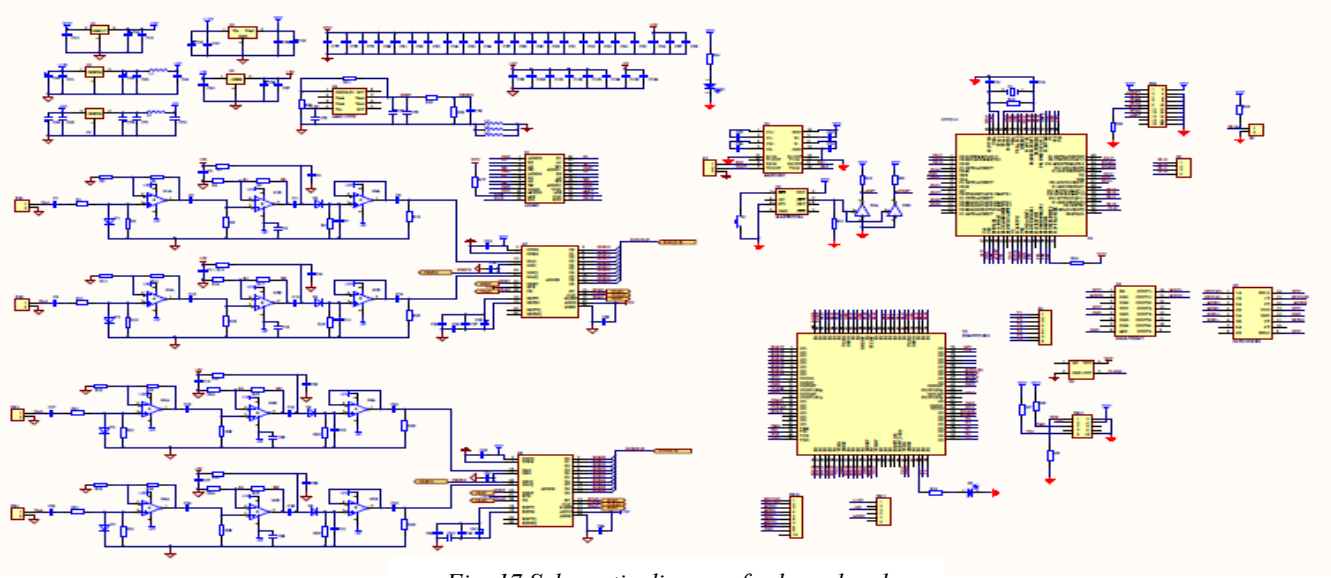

Fig. 17 Schematic diagram for laser head

IV. CONCLUSION

The Laser Warning System (LWS) is designed to provide enhanced platform survivability for today's Battle field environment. It does this by providing the crew with early warning of Laser Rangefinder and Designator threats, thereby allowing evasive action to be taken and thus increasing platform survivability. The system provides coverage over a wide range of single, continuous and multiple pulse lasers. LWS can be Integrated into the platform management system or provide laser warning for a defensive aid system. To protect the important target from attacks, sensors are integrated onto the platform to provide optimum 360° Coverage. Also, LWS has an extremely low false alarm rate with a typical response time.

Reference

[1] M. F. Heweage, A. M. Mokhtar, and M. A. Soliman, "Modeling and performance analysis of a quad detector," ASAT-14, 2011.

[2] Introduction to Infrared and Electro-Optical Systems. Ronald G. Driggers, Paul Cox, 2012.

[3] Wang Yong-zhong.Modern Military Optical Technology [M]. Beijing: Science Press,2003:288,384.

[4] Bonnie Baker Contributed By Digi-Key's North American Editors 2017-06-28

[5] Zeng Qing-yong, Weak Signal Detection[M]. Hangzhou:Zhe Jiang University Press,2002:12

[6] WANG Ming, ZHANG Ji-long, TIAN Er-ming etc. Detectability analysis of laser warning receiver based on grating diffraction[J]. Infrared and Laser Engineering,2008,VO1.37 No.4:683,686.

[7] David H pollock,The Infrared,Electro-Optical Systems Handbook Volume 7,Countermeasure Systems [M]. Infrared Information Analysis Center Enviromental Research Institute of Michigan,1993,77~140

[8] XIE Xue-kang, WU Jian, HU Yu. Simulation Of Warning To Laser Guided Signal[J]. Applied Optics,2002,Vol.23,No.2:26,30

[9] F.Giannini, E.Limiti, G.Orengo, A.Serino, M.De Dominicis, A High Gain-Bandwidth Product Distributed Transimpedance Amplifier IC for High-Speed Optical Transmission Using Low-Cost GaAs Technology, Department of Electronic Engineering, University of Rome "Tor Vergata", Via del Politecnico 1, 00133, Roma, Italy, 2002.

[10] X1. Zhang Jilong, Wang Zhi-bin, Li Xiao, Tian Eerming. A Review of Laser warning Receiver Based on Spectral Discrimination and Coherent Detection, Journal of Test and Measurement Technology, Vol. 20, No. 2, 2006, pp. 95-101. 2