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The design and implementation of photoacoustic based laser warning receiver for harsh environments

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ABSTRACT

This paper discusses the implementation of new type of laser warning receiver (LWR) system, based on the detection of photoacoustic signals, induced by high power infrared laser designators pulses on target's surfaces. This system appends conventional optoelectronic based LWR to decrease the false alarm rate (FAR) in harsh environments, where ambient conditions are expected to obstruct optical LWR. To improve the sensitivity of the photoacoustic based LWR system, some metallic and polymeric target shielding materials were studied, in order to cover a friendly civil structure, vehicle or a maritime entity with a low cost large area acoustic detector array shield. A thermographic investigation of target surface material- laser reaction, signal processing and system configuration and functional analysis are also presented.

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1. Introduction

Since the threat formed by long-range laser guided weapons began to spread [1–3], the reliance on LWR systems to protect friendly structures, ground, maritime and even air units also, increases [4]. The reliability of such early warning systems is the key of success, to properly activate the dedicated countermeasure versus this kind of attacks [5]. However, some problems arise in this concern, mainly the high false alarm rate for most LWR (which is typically about one per day [5,6]). This problem forces designers to include the human factor in the threat confirmation loop before launching the counter measures [5], to insure maximum trustworthiness at emergency time. The thing that may place some limitations on the installation of LWR systems to protect large structures and buildings, where such FAR could cause catastrophic mass population panic on daily bases!. Therefore, we decided in this work, to take advantage of the fact that, nanoseconds high power laser pulses (similar to that of laser designators) induce photoacoustic waves on solid surfaces [8]. This phenomenon is being used to design a complementary LWR that detects the laser generated acoustic pulses from the target's surface. A selective bandwidth contact sensitive microphones (piezoelectric transducers), will trigger then the warning alarm, and overcome the drawbacks of conventional optoelectronic systems. This enhancement could lower the FAR level significantly even at harsh operation environment, if both systems are deployed simultaneously.

1.1. An overview on optoelectronic based LWR system

LWR is a type of warning system used as a passive self-protection measure that detects, analyzes, and locates direction of laser emissions from laser guidance systems and laser range finders (LR). Then it alerts the crew of the protected entity, and can start various countermeasures, like smoke screens, laser dazzler or laser jammers and deception systems. Most non imaging LWR are having almost the same configuration shown in Fig. 1, where the major components are namely, the array of optical detectors distributed around the entity, the junction box, the threat monitor/alarm, the communication network and the countermeasure (optional).

The response time of LWR systems is very small to allow countermeasure engagement before threat interception (usually, the time to impact after detection (TTI) is ranging from 3 to 6 s) [5].

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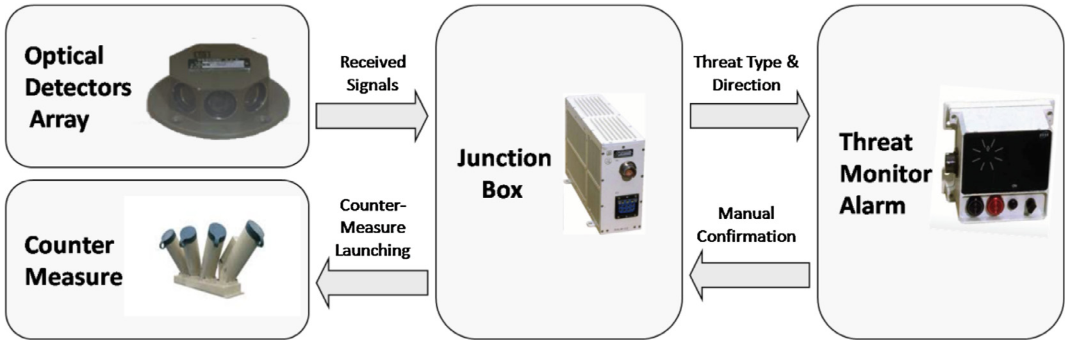

Fig. 1. Building blocks of most common non imaging optoelectronic LWR.

LWR systems are basically characterized by several parameters, where the most important are the spectral range, the dynamic range, the angular detection resolution, the capture range, the response time (Tr), the probability of detection (POD) and the false alarm rate (FAR) [5,9]. LWR systems are designed to detect any modulated laser radiation falling inside their detection field of view (FOV) that must cover all possible threat directions and angles of arrival around the protected entity. The threat discrimination is based on; the detected beam coherence [10,11], laser beam direction of arrival [12], and signal arrival time [5]. To differentiate between laser range finders (LR), laser designators (LD) and laser beam rider (BR), the classification of the threat type is based on laser beam wavelength and intensity, modulation frequency (for BR), pulse duration and repetition rate (for LR and LD) [5] as shown in Fig. 2.

The accuracy of which threat angle is being determined depends upon the number of used optical detectors around the protected entity, its angular responsivity and the quality of the used signal processing devices [5]. We shall limit our interest only on the detection of threat formed by high power pulsed infrared laser, delivered by long range airborne designation pods and rangefinders, with peak power of several megawatts per pulse, repetition frequency of 10–20 Hz, pulse time ranging from 5 to 20 ns, energy per pulse of 80 to 150 mJ, wavelength of 1064 nm and beam divergence of 0.035 mrad, since most of the deployed long range laser guided munitions work on similar guidance beam specifications [13,14].

2. Photoacoustic versus optoelectronic LWR

Acoustic detection of designation beam is achieved by installing an audio microphone behind a special photoacoustic shield covering the protected entity. As shown in Fig. 3, the structure of the acoustic detector shall not be quite different from that of the optoelectronic detector. However, the parameters used for the characterization of optoelectronic based laser warning receiver (OLWR) may not be suitable for characterizing photoacoustic based laser warning receiver (PLWR), because of the major difference between their modes of operation. OLWRs can detect off-axis scattered laser beam, and have a capture range around the protected entity, unlike PLWRs that detect on-surface laser spots. We manage to find the equivalent basic parameters needed to complete the characterization analogy as described in Table 1.

Many references reported that conventional LWRs deployed in harsh environments, might trigger false alarm [5–7,15–18], after being subject to certain optical or thermal radiation or electromagnetic noise, and may fail to sense the threat direction correctly. It is also possible, that these systems may not work at all at certain environmental conditions, Table 2 summarizes most reported in-

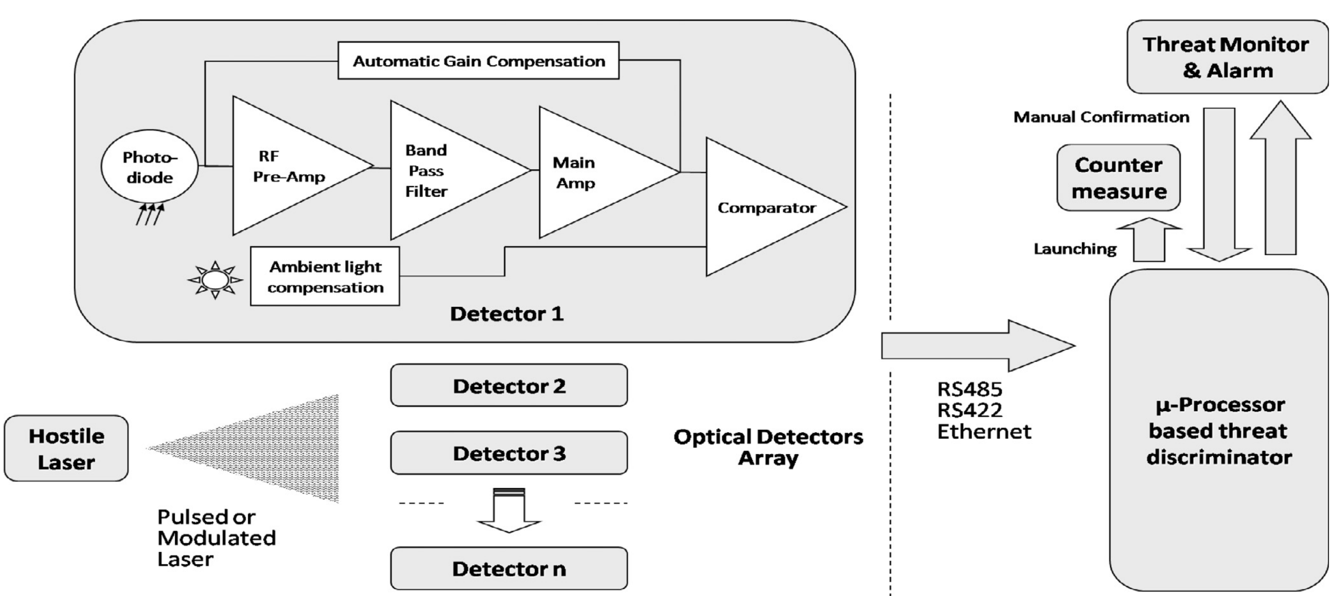

Fig. 2. Block diagram of optoelectronic LWR system.

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