EFFICIENCY OF A LIDAR SPEED GUN

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Abstract— This paper aims at improving the efficiency of a LiDAR speed gun. The efficiency of a LiDAR gun can be improved by adopting improved usage techniques and methods. The improved LiDAR gun usage methods can be helpful in achieving the correct velocity of the target and help security and police forces to maintain law and order, enforce vehicular speed limit and help citizens travel safe.

Keywords— RADAR Gun, LiDAR Gun, Doppler Effect, Efficiency.

I. INTRODUCTION

There was a need of a device which can calculate the target’s velocity in order to enforce vehicular speed limit. RADAR gun was the first device which was invented to calculate the target’s velocity. RADAR guns are replaced LiDAR guns as LiDAR guns gave more accurate results than RADAR guns. LiDAR guns efficiency can be increased by vanquishing their drawbacks.

II. RADAR GUN

RADAR Speed gun is a device used to measure the speed of moving objects. It is used to measure the velocity of moving vehicles and it is often used in profession spectator sport, for such things as the measurement of the speed of pitched baseballs, cricket balls, runners and tennis serves. It was used for speed limit enforcement. The acronym of RADAR is Radio Detection and Ranging. There are different types of RADARs based upon the frequency they use.

A. Mechanism of a Radar Gun

RADAR Speed Gun is a device which is built on the principle of the Doppler Effect. Doppler Effect causes the received frequency of a source (how it is perceived when it gets to its destination) to differ from the sent frequency if there is motion that is increasing or decreasing the distance between the source and the receiver. This effect is readily observable as variation in the pitch of sound between a moving source and a stationary observer.

\[
v = \frac{\Delta f \cdot c}{f \cdot \frac{2}{c}}
\]

Fig. 1 Formula of Doppler Effect

RADAR gun consists of a radio transmitter and receiver. The radio transmitter transmits a radio signal in a narrow beam and the reflected signal is received back, the difference in the frequency is calculated and the above formula is used to determine the velocity of the target (v) where c is velocity of light, f is frequency of the emitted radio wave and \(\Delta f\) is the difference between the transmitted frequency and received frequency.

B. Drawbacks of a RADAR Gun

The antenna which is used in a radar gun has a diameter of 2 inches (5.1cm). The antenna produces beam energy in form of a cone whose angle is 22 degrees surrounding the line of sight and 44 degrees in total width. This region is called as a main lobe and the intensity of the waves is maximum in this region. The region extending from 22 degrees to 66 degrees away from line of sight is called as side lobe, the intensity in this region is low and is approximately 20 times less than the intensity in the main lobe and this equivalent to decrease in 13dB in side lobe. When we try to determine the velocity of the target using a radar gun, the RADAR gun not only measures the velocity of the target but also other multiple objects this is because of side lobe.

We use continuous-wave radar to make the guns easy to make them mobile. When more than one moving objects are within the main and side lobes’ field view, the gun can measure the velocity of any one of the moving object and give us false reading of the actual target velocity. This defect can be eliminated by using pulsated operated signals, where we can also calculate the distance of the target thereby coming to know which device we aimed at.

We can narrow the field of view by increasing the frequency of the transmitted wave or by side lobe blanking method.

III. LIDAR SPEED GUN

LiDAR Speed Gun is a device which can determine the velocity of target by emitting a laser and processing the received signal by using a microprocessor. They are capable of producing reliable range and speed measurements in typical urban and suburban traffic. The acronym of LiDAR is Light Detection and Ranging.

A. Mechanism of a Lidar Gun

The mechanism of a Lidar Gun can be described in a sequence of events that happen in a fraction of seconds.
1) **Aiming:** The security officer aims at the target through a telescopic monocular built in a LiDAR gun. The security officer is trained to aim at known points which have high reflective surfaces of infrared waves.

2) **Firing Laser:** After aiming at the primary reflectors, security officer triggers the pulses of infrared waves on to the target by pulling the trigger and shooting at the target. Initially a single pulse(X) is released onto the target and then another pulse(Y) is released after a time interval (pulse gap time) and the time interval is measured in nanosecond and this process continues up to few hundred impulses. The time is measured by a high-speed and high resolution timer built inside the LiDAR gun.

3) **Reflection:** The laser on striking the target reflects back to the receiver end of the LiDAR gun and the time of receiving of the laser by the gun is precisely calculated by the high-speed and high-resolution timer.

4) **Processing:** The algorithms processed by a microprocessor of a LiDAR gun works on a basic definition of speed i.e. speed is equal to ratio of distance travelled by and time taken to cover the distance. Initially a pulse(X) is released from the gun and gets reflected back to the gun on striking the target after a time interval (t1). The time interval (t1) is halved, as t1 is the time taken for the full flight. The time interval (t1) is multiplied with velocity of light as velocity of infrared waves is same as light velocity.

From the above calculations we can determine the distance of the target at the second instant. We can find the velocity of the target by calculating the ratio of the distance travelled from first instant to second instant and difference in the time intervals for the first and second instant. In reality, the above calculations are performed by many impulses and then the velocity of the target is displayed on the LCD. We can also know whether the target is accelerating or decelerating.

**IV. EFFICIENCY OF A LIDAR GUN**

The efficiency of a LiDAR gun can be achieved by vanquishing the drawbacks of a LiDAR gun. Generally, wrong procedural techniques lead to false readings for a LiDAR.

A. **Drawbacks of Lidar Gun**

1) The laser emitted by the LiDAR gun has a RADAR beam as a cone i.e. narrow at the antenna and widening as it heads towards the target. The narrowest of RADAR beams diverge to a great extent on reaching the target therefore the target and its neighbouring vehicle will also be considered. This is one of the major drawbacks of the laser.

2) The advantage of using an infrared wave is to reduce the side lobe region and as frequency of infrared waves is high when compared to the frequency waves used in RADAR guns but the usage of same infrared waves has a huge disadvantage for humans. LiDAR guns use 50W energy which can affect humans when this laser strikes them. Consumer “eye safe” laser are limited up to 10milliwatts. The frequency used in LiDAR gun has a potential threat to humans.

3) The natural factors (weather) like rain, heavy fog, snow or any other precipitation affects the security officer who is using the instrument as the visibility level in such atmosphere decreases and he will not be able to aim the target accurately. The natural factors have negligible impact on the laser or LiDAR gun.

4) **Obstruction by the Sun:** Shooting at targets which have sun in the background can prevent the LiDAR from achieving accurate reading as the sun’s infrared waves may destructively interfere with the emitted infrared pulses of the LiDAR Gun. The sun also minifies the visibility of the security officer to aim at the target.

5) **Sweeping Error:** This is the most common error committed by the security forces. The security officer’s hand may be sweeped from the trigger instead of squeezing of the trigger.

6) **Radio or Microwave Interference Error:** When there is a radio or microwaves in the surroundings due to natural or manmade they interfere with the infrared waves and produce erroneous results. Common sources of electromagnetic interference include airport radar; microwave transmissions; transmissions of CB, ham, VHF/UHF, and cellular two-way radio/ telephones, including police and business radios; faulty sparkplug wires; mercury vapour and neon lights; high-tension power lines; and high voltage power substations.

7) **Mechanical Interference Error:** If there is any moving object other than the target vehicle then the LiDAR produces results of the moving object and not the target vehicle. Examples of mechanical interferences are rotary signs near the roadway, fan blades inside the patrol car.

8) **Antenna Position Error:**
The radar beam travels in a straight line, neither bending around curves nor following the contour of hilly terrain. If the antenna is not properly positioned, it may seem to clock an approaching car when, in fact, it’s clocking another car in the background.

9) Look Past Error:

![Fig. 3 Pictorial representation of look past error](image)

This error is caused due to wrong perception of the operator. Even if the operator aims his antenna properly, radar is still subject to “look-past” error. This is caused by the radar looking past a small reflection in the foreground to read a larger reflection behind.

10) Vehicle Interference Error:

![Fig. 4 Pictorial representation of vehicle interference error](image)

This error occurs when moving radar is used in traffic. For example, traffic ahead can confuse the radar’s estimate of patrol speed. Moving radar calculates target speed by subtracting patrol speed from the closing speed of the target. Therefore, anything that produces a low evaluation of patrol speed will automatically result in a high speed reading of target speed.

11) Cosine Error:

![Fig. 5 Pictorial representation of Cosine error](image)

Cosine error produces a result similar to interference error except no moving traffic need be present. A stationary object adjacent to the road, such as a building, or road machinery, or even a sign, makes a more efficient reflector, hence the name Cosine error. Since cosine error always makes patrol speed smaller than it actually is, it always acts to raise the reading of target speed.

12) Double Bounce Error:

![Fig. 6 Pictorial representation of Double bounce error](image)

Microwaves are easily reflected. That is an advantage of LiDAR gun over RADAR guns but the security officer must be aware of the difference between an ordinary reflection and a bad bounce. Big vehicles such as trucks are very good reflectors and they produce false readings.

13) Beam-Reflection Error:

![Fig. 7 Pictorial representation of Beam-reflection error](image)

As microwaves are readily reflected, it is not recommended to maintain the antenna within the patrol car. There is a great possibility that a reflective can be set up through the rear-view mirror that will produce radar readings of vehicles behind the patrol car when the radar is aimed forward. All those vehicles behind can be either coming or going, since radar does not distinguish directions and can interpret false readings.

14) Road-Sign Error:

![Fig. 8 Pictorial representation of Road-sign error](image)
As microwaves have great power of reflection. The sign boards which are off the road can reflect back the waves and give us ghost readings.

V. EFFICIENCY OF A LIDAR GUN

We can overcome the drawbacks of LiDAR by following proper procedures thereby increasing the efficiency of a LiDAR gun.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Category of Reflector</th>
<th>Vehicular Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Primary Reflectors</td>
<td>Front and Rear License Plates</td>
</tr>
<tr>
<td>2.</td>
<td>Secondary Reflectors</td>
<td>Headlight, turn signal indicators and tail lights, bumper guard</td>
</tr>
<tr>
<td>3.</td>
<td>Tertiary Reflectors</td>
<td>Windshields and Vehicle external body</td>
</tr>
</tbody>
</table>

The table above illustrates us about the different categories of reflector present on a Vehicle:

- **Primary Reflectors:** The reflectors which have the highest reflective power to reflect the incident infrared waves are called as primary reflectors. The security officer aims at the primary reflectors to achieve the most accurate results. Best reflectors are front and rear license plates and headlight for automobiles and motorbikes respectively. Front and rear license plates are painted with high reflective retro-reflective coating that has the maximum ability to reflect infrared waves to the receiver. Headlight is considered as a primary reflector in case of a motorcycle as the headlight is usually in a semi-parabolic reflecting surface and there by aiding in reflection.

- **Secondary Reflectors:** The reflectors which can aid the security forces to achieve accurate reading when the target is in short range but gives false readings for long range detection. Secondary reflectors are headlights, turn signal indicators, tail lights and bumper guards. Headlights are secondary reflectors for an automobile. We can also determine which car we are aiming at among cars of similar model as the primary reflector is a license plate and has unique identity number.

- **Tertiary Reflectors:** The reflectors which are poor reflectors of the infrared waves are called as tertiary reflectors. These reflectors are windshields and vehicle external body. The security officers can achieve accurate reading by aiming at primary reflectors than secondary and tertiary reflectors. We can also determine which car we are aiming at among cars of similar model as the primary reflector is a license plate and has unique identity number.

The security officer should always try to aim at the primary reflectors which can increase the accuracy of the clocked speed.

Sweeping Error is the most common error. The error can be nullified only by the security officer who is trying to determine the speed of the velocity. The security officers should be very careful not to move his hand till the result is displayed on the LCD display.

Radio, Mechanical, Vehicle Interference error, Antenna Position error, Look Past Error, Cosine error, Double Bounce Error, Beam-Reflection Error and Road Sign error are the error which are completely caused only due to wrong procedures followed by security forces. These errors can be avoided and eliminated by educating the security forces about the errors which can ultimately increase accuracy of the LiDAR readings.

VI. EFFICIENT LIDAR GUNS

The proper usage of LiDAR guns can make them very efficient. The efficient LiDAR guns can be very useful in implementing speed limit enforcement.

The current records reveal that 2.2% of the world population die in road accidents. According to World Health Organization guidelines to reduce road accidents:

1. **Countries need to set speed limits that reflect the function of individual roads.** In doing so, they should consider the types of vehicles using the road, the nature and purpose of the road, roadside activities, provision of facilities for vulnerable road users, and the frequency of use by pedestrians and cyclists. Increased priority should be given to vulnerable road users, notably in urban areas, where speed limits should not exceed 50km/hr.

2. **Local authorities need to be given the authority, resources and political support to implement measures to reduce speed limits to levels that may be lower than national limits where vulnerable road users are particularly at risk.**

3. **Programmes put into place to address speeding need to foster a public awareness and understanding of the effects of speeding and the reasons for enforcing speed limits.**

From the above guidelines, we can conclude that WHO gives great emphasis on speeding vehicles. Therefore we need to make more efficient LiDAR

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CONCLUSION

We conclude that by making efficient LiDAR guns we can reduce the road accidents. Efficient LiDAR guns can be made by following proper procedures while clocking the velocity of the target, this can be done by educating the Security forces about the errors committed during the operation of a LiDAR gun.

ACKNOWLEDGMENT

We wish to acknowledge and thank Dr. Dattathreya Reddy, Dr. T.D. Bhatt and Ratna Deepthi Medapati of their great contribution for this paper. We express our sincere gratitude to my professors and families for their continuous support through their patience, motivation, enthusiasm and immense knowledge.

REFERENCES

5. Project: What is Doppler Effect?, *Qualitative Reasoning Group*, Northwestern University.

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