STATIONS FOR TESTING LASER RANGE FINDERS

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ABSTRACT:

In spite of apparent simplicity of work concept testing medium/long range laser range finders is a difficult task both during field tests and laboratory tests. A short review of methods used to test LRFs is presented in this paper. Two test stations that enable expanded testing of LRFs are presented two.

1 INTRODUCTION

Laser range finders (LRFs) are one of most important and commonly used types of optronic systems in both military, paramilitary and civilian applications.

Testing LRFs look apparently very simple. Just to shoot and check at which conditions the tested LRF generates proper distance indication. Practically situation is much more complicated.

Testing is a relatively easy task only in case of short range (range below say 1 km) LRFs used in recreational applications like golf, hunting etc. Final users of such LRFs with basic technical know-how can easily carry out accurate performance tests by shooting to a series of real targets at field conditions [1-2]. Situation becomes much more difficult in case of medium/long range (distance from about 2 km to 40 km) LRFs used in military/paramilitary application due to two reasons.

First, results of field tests of medium/long range LRFs depend on atmospheric conditions and this dependency significantly reduces repeatability and accuracy of necessary field tests.

Second, field tests of medium/long range LRFs done by shooting to real military targets are costly, time consuming and often difficult to carry out due to a set of logistical problems.

Due to these two reasons final evaluation of military type LRFs is rarely done by shooting to real targets at field conditions. At the same time situation on market is rather chaotic. Some manufactures of LRFs present in catalogues value of maximal range calculated for perfect atmosphere, and some even present maximal range as a maximal distance that can be detected by receiver electronics in case of hypothetical strong pulse. Only a small group of manufacturers of LRFs present in catalogues measurement data that enables relatively precision performance evaluation of these LRFs.

It may be surprising to readers to learn that in spite of importance of LRFs for modern armed forces testing and evaluation of these devices has received small attention. It is difficult to find even a dozen of scientific papers devoted to this subject that were published during last decade [3-8]. There are no standards that regulate testing military LRFs. There are no books devoted to testing LRFs. Situation with testing LRFs is in sharp contrast to situation with testing thermal imagers where there are military standards, a long series of scientific papers and educational books. There are several manufacturers of commercial test systems [9-11]. However, in absence of international standards these manufacturers propose different solutions for testing LRFs.

This paper present a review of of present metrology of laser ranging. The paper present also new test stations that could potentially significantly improve situation in this metrology.

2 METHODS OF TESTING LRFs

Final users of military type LRFs are mostly interested to know this set of parameters:

1. maximal operational range,
2. minimal discrimination distance (minimal distance at which two targets can be discriminated),
3. measurement accuracy,
4. angular size of laser beam (related to minimal angular size of target of interest),
5. boresight errors (how accurately target of interest can be shoot).

All these parameters are directly or indirectly related to operational performance of LRFs but the first one is considered as the most important.

Methods of testing LRFs can be divided onto two main groups: A)Field tests, B)Laboratory tests.

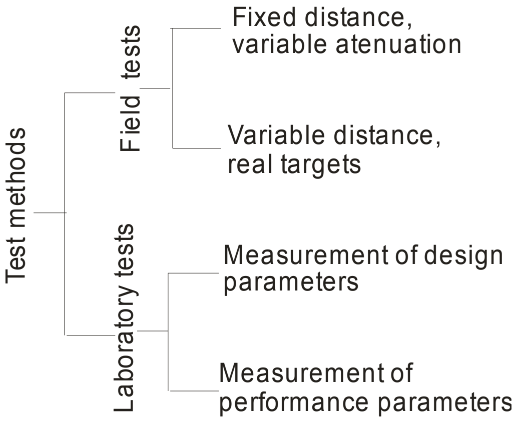

Fig. 1. Division of methods to test LRFs

Tests from group A can be further divided into two groups:

1. Shooting LRFs to real targets located at

long distances,

2. Shooting LRFs to artificial targets located at short distance via a medium of regulated attenuation.

Field tests of LRFs using method 1 are rarely done due to significant drawbacks of this method (high result variability due dependency of test results on variable atmospheric conditions, and high cost of field tests with real targets). Method no 2 is much more popular.

In detail method no 2 proposes to measure at field conditions a single parameter called extinction ratio (ER). Measurement of this parameter is typically done by shooting the LRF into direction of a small reference target placed at some relativeley short distance, attenuating radiation emitted/received by tested LRF, and checking at what attenuation level the LRF stops giving proper distance indications. In this way Extinction Ratio can be understood as a maximal attenuation (in dB) when tested LRF is still capable to work properly. The distance between the tested LRF and test target is typically typically in range from 0.5 km to 1.2 km. The rule is that the distance should be long enough to assure that time dependent gain in receiver electronic is at maximal level. There is not standard that regulate measurement of ER of LRFs. Different manufactures do tests at different distances and using targets of different reflectance.

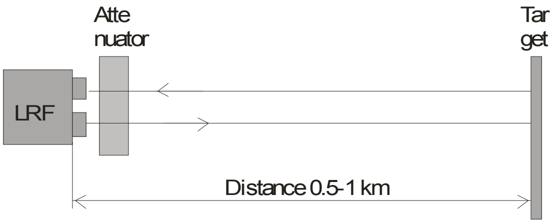

Fig. 2. Diagram of system for measurement of ER at field conditions (method no 2)

There is a direct relationship between ER and maximal operational range of tested LRF. Therefore measurement of ER can be potentially considered as final performance tests of military type LRFs. Apparently drawbacks of method no 2 are the same as drawbacks of method no 1: field measurements of ER are costly, time consuming and sometimes variable due to unpredictable behavior of atmosphere. However, drawback of method 2 are the same as of method no 1 but at much lower level. Costs of field tests using method 2 are several times lower than costs of similar tests using method no 1. Repeatability and accuracy of ER measurement using method no 2 are several times better than repeatability and accuracy of measurement of maximal operational range using method no 1.

Due to direct relationship with maximal perational range ER is considered as the best parameter to evaluate performance of military type LRFs in specialist literature [11-13]. Next, ER parameter is typically presented in catalogs of high-end LRFs [15-18].

Ideal laboratory tests should deliver the same information about performance of tested LRFs as provided by field tests but during tests at convenient laboratory conditions. The laboratory tests can be divided into two main groups:

1. Measurement of design parameters.
2. Measurement of performance parameters.

The first method based on a concept of measurement at laboratory conditions a series of parameters like pulse energy (or pulse power), pulse time width, pulse repetition frequency, beam divergence, receiver sensitivity. These parameters are later used for indirect determination of performance capabilities of tested LRF.

The second method is based on idea of direct measurement of performance parameters like ER, distance discrimination, accuracy, boresight errors at laboratory conditions.

Majority of commercial test stations use exclusively method 1 [9,10] but test stations based on method 2 are under development [13,14].

This paper present results of project to develop test stations capable to use both methods of laboratory testing [19]. Two test stations (coded as LTF and LTE) are presented:

- LTF station – to enable performance tests of LRFs at laboratory conditions,
- LTE station – to deliver support for ED project.

3 STATION FOR PERFORMANCE TESTS

LTF station is a compact, mobile test station based on a concept of a test station that would imitate in laboratory/depot conditions measurement of extinction ration ER of tested laser range finders without necessity of time consuming, costly field tests.

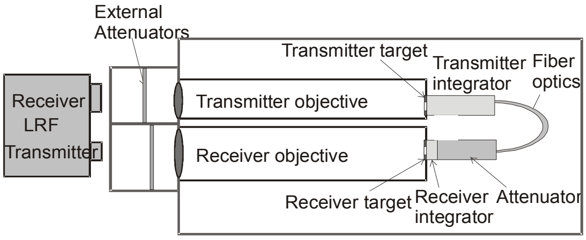

Fig. 3. Block diagram of LTF test station

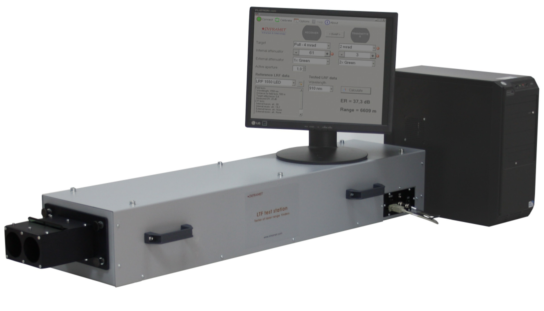

Fig. 4. Photo of of LTF test station

The LTF station is built from two main blocks: LTF main block and PC with software. The LTF main block is built from external attenuator module, receiver objective, receiver target, receiver integrator, receiver attenuator, fiber optics, transmitter attenuator, transmitter integrator, transmitter target and transmitter objective. When transmitter of tested LRF emits optical pulse the receiver objective focuses incoming laser radiation at plane of the receiver target plate. The latter module simulates the small reflector target used during ER measurement – only radiation that hits the target can be transmitted. Next, the receiver integrator converts incoming directional radiation into diffuse radiation that is latter attenuated using receiver attenuator module. After this the fiber optics (fixed istance about 1.2 km) transmits incoming radiation with some temporal delay. At the end of fiber channel is located transmitter attenuator that reduces again power of laser pulse. Next, the transmitter integrator improve conversion of incoming directional radiation into diffuse radiation. Finally, the transmitter optics emits collimated beam into direction of receiver of the tested LRF. Divergence angle of emitted beam is by size of transmitter target.

Both targets (receiver target, transmitter target) emit visible light. Therefore it is easy to test team to align tested LRF with optical axis of LTF station if tested LRF is equipped with optical viewer or cooperate with a TV camera.

It should be also noted that LTF station use symmetrical design. Therefore the convention transmitter/receiver is only for clarification of method of work presented earlier. In fact both channels of LTF can work as receiver channel or transmitter channel depending on design of tested LRF.

Measurement of ER is the main task of LTF station. However, the station can simulate several targets located at different distance and enable measurement of distance discrimination.

Tab.1 Parameters of LTF test station

Parameter	**Value**
Spectral range	700-1700nm
Calibrated wavelengths	Typical: 1060nm, 1550 band (1540, 1550, 15570), 910 nm
Number of simulated targets	One (option up to three)
Simulated target distance	About 1200 m
Simulated attenuation range	At least 40dB
Attenuation regulation method	Motorized, PC control
Max target size	4 mrad
Minimal target size	0.25 mrad
Regulation of target size	Step regulation, five values
Control of target size	Motorized, PC control
Ability to simulate boresight errors	Yes, simulation of non parallel axis of transmitter and receiver
Max acceptable diameter of transmitter optics	50 mm (models with bigger optics can be delivered)
Max acceptable diameter of receiver optics	50mm (models with bigger optics can be delivered)
Design optimisation	Testing LRFs having two separate channels (LRFs having coaxial optics can be optionally tested)
Location of tested LRF relative to test station	LTF optics must overlap optics of tested LRF
Work temperature range	5°C to 40°C
Storage temperature range	-5°C to 60°C

As can be seen from the description presented earlier LTF test station is based on a simple concept of fiber optics loop to create temporal delay of transmitted laser beam and simulate a target at desired distamce. This concept has been known for decades. However the crux of LTF station is not the fiber optics loop but a set of calibrated attenuators. Measurement of ER of all types of LRFs (monopulse/ multipulse, short range/long range) requires calibrated attentuators capable to offer precision regulation of transmitted optical power with at least 10 000 times dynamic. This value does not sound specially impressive if we compare to othe optical attenuators but we could keep in mind that attenuators used in LTF station must also witstand optical pulses of peak power over 10 MW.

In detail LTF station use a set of 4 calibrated attenuators. The first two are external attenuators made from glass windows of limited transmittance. The third one is a set of electrically controlled optical plates of variable transmittance (step regulation of attenuation). The fourth is an optical pipe of regulated length and transmittance (continuous regulation of attenuation). All these attenuators combined together offer desired attenuation.

4 STATION FOR DESIGN SUPPORT

LTE test station enables to use both main methods of testing LTFs: a)measurement of a series deisgn parameters(pulse energy, pulse peak power, pulse time width, pulse frequency, beam divergence, receiver sensitivity, accuracy of distance measurement, distance discrimination, and bore-sighting errors), b)measurement of Extinction Ratio.

Such unique ultra wide test capabilities have been achieved by using dual design of LTE test station. The station can work in two modes. Electronic simulation mode and fiber optics simulation mode. In the first mode advanced electronic modules are used to measure parameters of pulses emitted by transmitter of tested LRF and to generate optical pulses into direction of receiver of tested LRF. In the second mode simulation of reflected pulses is achieved using fiber optics circuit coupled with high-tech calibrated attenuators.

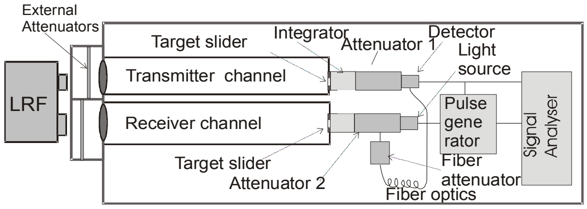

Fig. 5. Block diagram of LTE test station

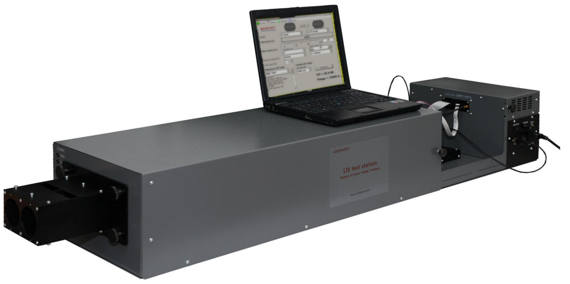

Fig. 6. Photo of of LTE test station

LTE test station working in fiber optics mode is practically earlier presented LTF station and only electronic mode will be discussed.

The LRF is located in position to have situation when optics of LTE station overlaps optics of tested LRF. The transmitter of LRF emits a single pulse (or a series of optical pulses). The transmitter objective of the LTE station focuses incoming laser radiation at plane of the transmitter target slider that regulates active size of optical integrator. The latter module uniformly integrates incoming radiation and passes it to attenuator module. After passing the attenuator the radiation reached optical detector module. The latter module converts incoming optical pulse into electronic pulse that is sent both to signal analyzer module and to pulse generator module. The signal analyzer module records temporal profile of incoming pulse and send such data to PC. Pulse generator module generates with some temporal delay electrical pulse that is sent to pulse light source. The latter module emits optical pulse that after suitable attenuation, spatial integration is emitted into direction of receiver of tested LRF.

LTE station offer advantages of both two methods of testing LRFs:

1. electronic simulation: measurement of parameters of pulses emitted laser transmitters, simulation of multiply targets at variable distance with variable pulse amplitude,
2. reliability of fiber optics simulation (temporal and spectral profiles of pulses coming to receiver match exactly profiles of pulses emitted by transmitter).
3. Some of test results obtained using electronic simulation can be verified by tests using fiber optics simulation.
4. Ultra expanded test range:
    - electronic mode: pulse energy, pulse peak power, pulse time width, pulse repetition frequency, missing pulse, pulse coding, distance measurement accuracy (test for both single target or multiply targets), distance discrimination, relative receiver sensitivity
    - fiber mode: extinction ratio ER, distance measurement accuracy (single distance).
5. Ability to test both monopulse LRFs and multipulse LRFs
6. LRFs working at all typical wavelengths can be tested: 905/910 nm, 990 nm, 1060nm, 1540nm, 1550nm, 1570nm.
7. Ability to simulate targets of different angular size (from 0.25 mrad to 4 mrad).
8. Fully computerized test system. Distance target-LRF, target size, system attenuation can be controled from PC. The incoming pulses and digitally recorded and analysed.

Tab.2 Parameters of LTE test station

Parameter	Value
Type of tested LRFs	Both mono-pulse LRF and multi-pulse LRFs can be tested Optimized for testing lRFs of two separate channels but coaxial LRFs can be tested
Spectral wavelength of tested LRFs	905/910 nm, 990 nm, 1060 nm, 1540 nm, 1550 nm, 1570 nm
Diameter of optics in two optical channels of LTE test station	60 mm
Mode of work	two manually switch modes: electronic simulation and fiber optics simulation
	Electronic mode
List of measured parameters	pulse energy, pulse peak power, pulse time width, pulse repetition frequency, missing pulses, pulse coding, distance measurement accuracy (test for both single target or multiply targets), distance discrimination, relative receiver sensitivity
Optical detector type	ultrafast, calibrated InGaAs photodiode (Si photodiode can be optionally delivered for tests of 905/910 nm LRFs)
Pulse energy range	10nJ to 200 mJ
Peak pulse power	1W to 10 MW
Pulse width	4-600ns
Resolution of pulse	⬅2ns (option ⬅1ns)

width measurement	
Pulse Repetition Frequency	from 0.1 Hz to 20kHz
Simulated distance	from 200m to 40 km (can be extended)
Resolution of simulated distance	2 m
Number of simulated targets	up to 3
Missing pulses	Yes
Coding	Yes
Receiver sensitivity tests	Yes
Central wavelength of pulsed light sources	905nm, 990 nm, 1060 nm, 1540 nm, 1550 nm, 1570 nm (the sources are to be manually exchanged)
Dynamic of regulation of peak power of simulated reflected pulses	at least 512
	Fiber optics mode
List of measured parameters	ER (extinction ratio), distance measurement accuracy (single distance), absolute receiver sensitivity, estimated range of LRF, distance discrimination (optional)
Test conditions for ER	LTE is calibrated for the following conditions: distance 500m, target reflectance = 0.4; target type: diffusive, Lambertian surface; visibility 20km, probability of proper indication: 90%
ER measurement range	up to 46 dB (limit depends on wavelength of tested LRF)
Simulated distance	about 1200 m (at distances over 1km all LRFs are working in maximal gain mode)
Absolute receiver sensitivity range	from about 0.1 nW to 10 μW (depends on measured peak power of tested LRF)
Conditions for range calculations	Software calculates the ranges on the basis of measured ER values and atmosphere attenuation data determined experimentally by Inframet
Distance discrimination	fiber circuit simulating up to 3 distances can be optionally delivered (typical version: single distance)
	Both modes
Divergence angle measurement	Yes (measurement using six step targets)
Measurement of aligning of the laser transmitter with internal optical sight/TV camera	Yes (measurement resolution 0.25 mrad)
Aligning of the laser receiver with the laser transmitter	Yes (measurement resolution 0.25 mrad)
Ability to test LRF with night vision sight	Yes
PC	typical modern laptop, Windows 7 operating system
Software	Set of computer programs: Pulse Browser, LE Control, LF Control, MET Control. Pulse Browser: to support acquisition and analysis of temporal profiles of pulses emitted by laser transmitter LE Control: to enable PC control of attenuators and target sliders working in electronic mode LF Control: to enable PC control of attenuators and target sliders working in fiber mode MET Control: program to enable control of pulse generator module (distance simulation in electronic mode)
PC communication	USB 2.0
Working temperature	+5ºC to 35ºC
Storage temperature	-5ºC to 50ºC
Humidity	up to 95% (non condensing)
Dimensions	1360x 33.50x230 (main module) plus typical PC dimensions
Mass	52 kg

5 ADVANTAGES OF DEVELOPED TEST STATIONS

Some important parameters of laser range finders can be accurately measured using simple measuring instruments: pulse energy using optical energy meters, or pulse width using high speed oscilloscopes. These measuring tools are rather low cost. Having a set of optical energy meter and a high speed oscilloscope at price level about 3 000 Eur we can measure accurately pulse energy and pulse width of all laser range finders present on the market. However knowledge about pulse energy and pulse width is not enough to evaluate performance of laser range finders at real conditions. The users of laser range finders are not specially interested in what are values of pulse energy and pulse width but what is measurement range and accuracy of their laser range finders at real life conditions. We must keep in mind that performance of LRF characterized by the same pulse energy can differ a lot. Therefore measurement of Extinction Ration (and optionally Distance Discrimination) is needed for final quality evaluation.

At the same time a long set of parameters like pulse energy, pulse peak power, pulse time width, pulse repetition frequency, missing pulses, pulse coding, distance measurement accuracy (test for both single target or multiply targets), distance discrimination, receiver sensitivity are needed to enable design optimisation during R&D projects.

Other desired features on ideal stations can be listed as: simulation of targets of different angular sizes, 2)simulation of multiply targets, 3)checking angular divergence of the emitted beam, 4)checking aligning of the laser emitter with reference optical axis, 5)checking aligning of the laser receiver with the laser transmitter.

The earlier discussed LTF and LTE test stations fulfill all these requirements on ideal stations for testing LRFs.

6 CONCLUSIONS

Testing laser range finders has received relatively little attantion from scientific community in spite importance of this technology at defense applications. Two novel computerized stations for testing LRFs are presented in this paper.

LTF station is a compact, mobile test station that enables to carry out final performance tests (measurement of extinction ration ER) of tested laser range finder at laboratory conditions.

LTE is the first commercially available test station that enables both measurent all design parameters (pulse energy, pulse peak power, pulse time width, pulse repetition frequency, missing pulses, pulse coding, distance measurement accuracy (test for both single target or multiply targets), distance discrimination, receiver sensitivity) of LRFs needed for R&D works and manufacturing line and final quality parameters (extinction ratio, operational range).

Both stations present unique features not met on market and enable tests of virtually all laser range finders.

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