SOLID-STATE LASER USED AS DIRECT FIRE SIMULATOR

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Holobeam, Inc. of Paramus, New Jersey has developed a new generation of Direct Fire Simulators (DFS) for the U.S. Army's Combat Development Command Instrument Support Group of Ft. Ord, California.

The laser based system gives realistic fire simulation for training men in mock battles and for evaluating novel strategy and maneuvers. The basic idea involves simulating direct weapon fire with a narrow beam of infrared light from a GaAs laser diode. Troops and vehicles carry detector arrays to receive laser transmitter pulses. Blank ammunition is used and smoke is generated to signify disabled vehicles.

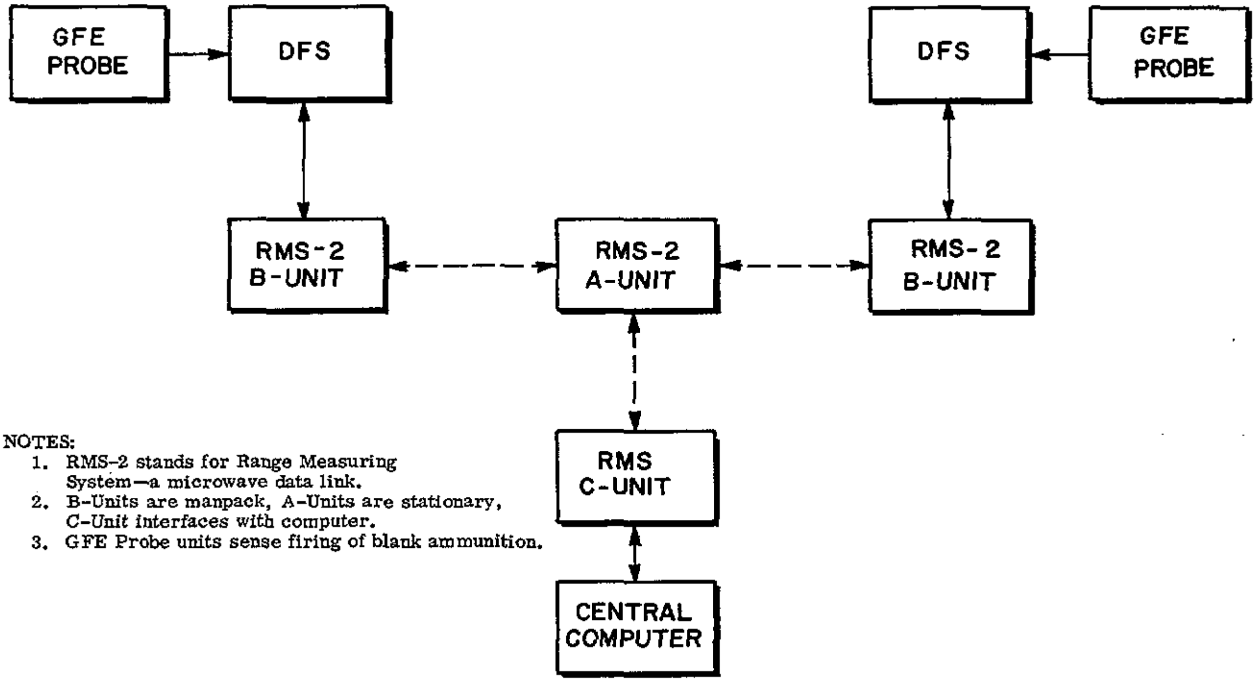
The key advantage of these simulators is realism combined with safety. Umpires used by old systems to score simulated battles are not required since the DFS itself scores and signals hits. The laser beams are low in level and are completely safe to the eye. Some of the other advantages are listed in Table 1.

There are two types of simulators that have been developed, one to operate with hand-carried weapons, such as the M-14 and M-16 rifles, the other for armored vehicles, such as the 105-mm tank-mounted cannon and the 106-mm recoilless rifles. The rifle simulator has a range of 500 meters while the vehicle simulator has a range of 3000 meters. Each weapon is assigned a code for identification. This code is used to modulate a gallium-arsenide injection laser. The laser signal being a group of invisible infrared pulses. The troops, as well as the armored vehicles, are outfitted with special infrared detectors which are capable of receiving the laser beams. When a detector intercepts a coded beam, this signal is decoded and processed to determine whether the owner of the detector should be declared "hit", and therefore be removed from the maneuvers. This "hit" decision can be made either by the simulator, on a probability basis, or it can be made by a real-time computer to which the Direct Fire Simulator is interfaced. (See Figure 1). If the computer is used for the decision, then information such as range, or the number and location of the detectors which intercepted the beam, may all be used to make the decision as realistic as possible. In either case, if a combatant is declared "hit", he is then informed of this fact by means of an audio warning device and the laser beam transmitter on his weapon is automatically deactivated.

The power output of the laser beam transmitters is precisely controlled and limited so as to always operate well within the limits of eye safety established as safe by the U.S. Army Surgeon General's office. At no time does the energy density ever exceed 10^{-7} joules/cm^2 at the surface of the eye.

Table 1. DFS Features

1.	Provides assessment of tactics and standard operating procedures to determine effectiveness.
2.	Provides corrective training in a highly interesting and allert manner which requires no motivation to maintain training interest.
3.	No expensive real estate or ranges required for operation.
4.	Provides means for training in confined areas—can be used indoors.
5.	Requires little target maintenance since it does not use destructive targets.
6.	Safe to operate and maintain.
7.	Provides adjustable beam sizes.
8.	Provides adjustable time delays in transmitters.
9.	Easy installation.
10.	Low acquisition and operating cost.



NOTES:
1. RMS-2 stands for Range Measuring System—a microwave data link.
2. B-Units are manpack, A-Units are stationary, C-Unit interfaces with computer.
3. GFE Probe units sense firing of blank ammunition.

Figure 1. Overall Combat Evaluation System

The Direct Fire Simulator employs a time code modulation technique* designed to enable high digital data transmission using a low speed data channel. The technique operates by establishing a coding relationship between time and information. To transmit a particular piece of information, a signal is transmitted at a point in time (with respect to reference) established as the code point. For example it is possible to transmit any one of a million numbers by a single pulse. (Normally this requires the transmission of 20 binary bits). This can be accomplished by dividing a second into a million parts, i.e., 1 microsecond time slots. Then to transmit a desired number a pulse is generated during the time of the appropriate slot. This technique is particularly useful for laser systems which have fairly low duty cycles.

The use of single pulses for particular messages provides the advantage that redundancy can be employed over a low data rate communicator channel. The particular message format employed by the DFS systems is shown in Figure 2.

System Details

Each Direct Fire Simulator is composed of a laser beam transmitter, three groups of detectors, a signal processing unit (Hippack) and the necessary power sources. Figures 3 and 4 depict block diagrams of the systems.

Transmitters

Two laser-beam transmitters have been developed, each consisting of a trigger unit, logic for a digital coding, a modulator and a gallium-arsenide laser. The transmitters are mounted on the weapons and are powered by their own battery supplies. When a weapon is fired, it produces a sound and flash, characteristic of the type of ammunition being simulated. This sound and flash is then used to trigger the digital coding logic and subsequently initiates the transmission of the laser beam. The transmitters provide either 1-, 5-, or 10-milliradian beam divergences. By providing these fixed-beam divergences, the size of the beam at 500 meters can be set to either 0.5, 2.5, or 5 meters. Holobeam has developed an optical system that provides 1-milliradian beam divergence and which is converted to 5 or 10 milliradians by a simple screw-on lens addition.

A special driver circuit has been developed, to provide the high-current, (30 ampere) short-duration pulses to drive the gallium-arsenide lasers. The 200-nsec pulse is generated by a capacitor discharge type circuit. The unique feature of this pulser is that no high-voltage power source is required.

The primary function of the transmitter coding logic is to pulse the laser beam in accordance with a specific code assigned to each weapon. Since fully automatic weapons may be employed at a later date, the transmitter is able to handle firing rates up to 6000 pounds per minute. Pulse repetition is limited to 1000 cycles per second with a 200-nsec pulsewidth. It is pos-

* Patent Pending 737,892

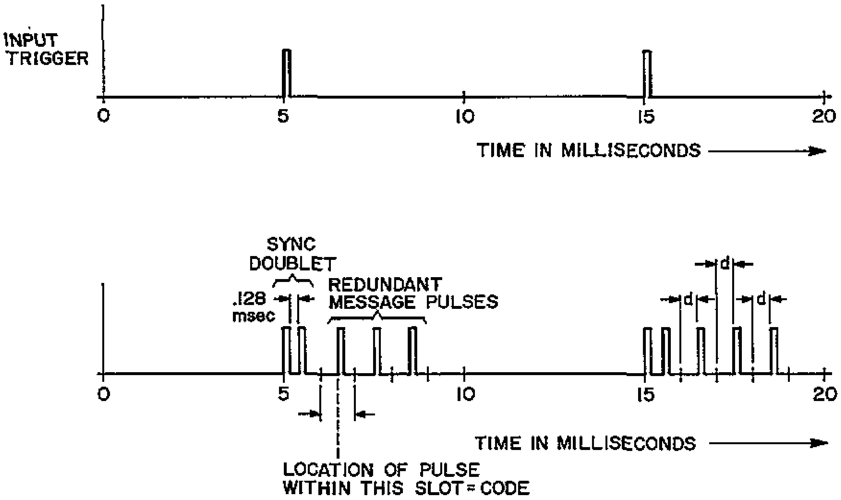


Figure 2. DFS Message Format

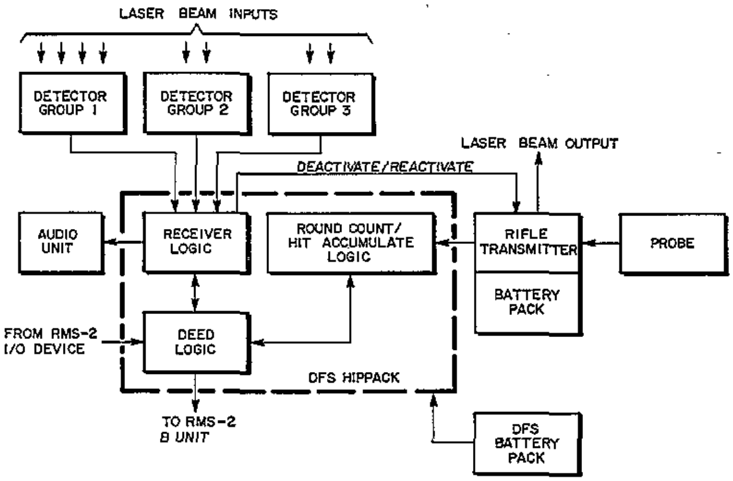


Figure 3. Infantry Simulator

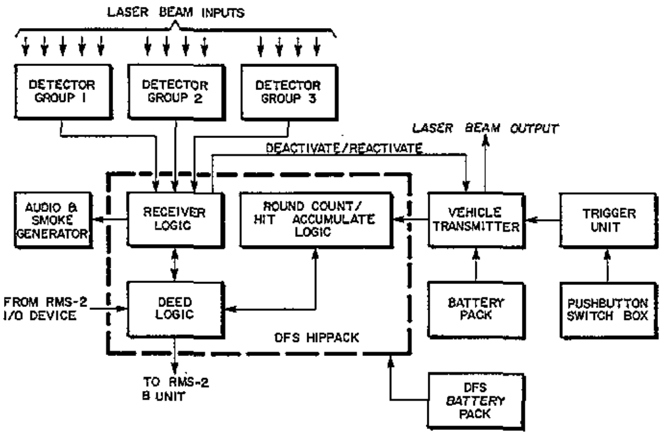


Figure 4. Large Gun Simulator

sible to increase this rate by employing a narrower pulsewidth; however, this would require a detector with a wider bandwidth. Another consideration is the desirability of transmitting the message more than once to enhance the signal-to-noise ratio at the detectors. With the Holobeam technique, the code information is transmitted several times without exceeding the maximum repetition rate in pulsing the gallium-arsenide laser, and the equipment can still simulate firing at more than 6000 rounds per minute. In the decoding process, a majority vote is taken to decode the message, and a single noise pulse would have no effect on the system.

For distances greater than several hundred meters, the periodic scattering and bending of the beam due to atmospheric scintillation becomes a potential problem. Analytical calculations corroborate actual field tests in establishing this scintillation effect. Scintillation causes an intensity modulation at particular points within the beam area as a function of time. The repetition rate of this modulation has been shown to vary between 10 and 100 cycles per second. There are two ways that this problem is overcome. One solution is to have a sufficient number of detectors on the target so that at least one of the detectors always receives the message, no matter how short it may be. The second solution is to repeat the message a sufficient number of times to ensure that a detector eventually will receive it. Although each infantryman has eight detectors, these are distributed in a rather small area compared to the size of the beam. For this reason, the simulator of the armored vehicle has its message repeated ten times (every 20 msec) to ensure a 90% probability of message reception at 3000 meters.

Receiver

The receiver consists of a group of detectors, a message decoder with alarm indicators, and circuitry interfacing to a computer. Each detector contains a photodetector diode with a 100° field of view and a high-gain preamplifier.

The photodetector diode senses the presence of a laser beam and converts it to a proportional current pulse. The preamplifier then converts this current pulse to a voltage usable by standard integrated circuits. Each detector is contained in a $1\frac{1}{2}$-inch-diameter, $\frac{1}{2}$-inch-deep housing. An infantryman taking part in the combat maneuvers is equipped with eight of these detectors distributed on different parts of his body arranged in three (3) groups. Four of them (Group I) are arranged into a helmet array resulting in a completely omnidirectional detection capability. Two of the detectors (Group II) are worn on the upper part of the body, while the other two (Group III) are on the lower part of the body. On the large armored vehicles, thirteen detectors are distributed to provide omnidirectional detection capability.

Signals received by any of the detectors are sent to a central message decoder. The function of the decoder is to determine the code of the transmitter whose beam was intercepted. Each of the information pulses is decoded into a binary word. After this is accomplished, a bit-by-bit majority vote is taken to obtain the actual code. This technique prevents single noise pulses from interfering with the reception of a proper message.

When an acceptable message is decoded, the wearer of the receiver is given a one-second audio warning tone to notify him that someone has shot at him. In addition, data indicating the code of the firing transmitter that did the simulated shooting and the detector group that received the message is stored in the computer interfacing circuitry. When this storage has taken place, the computer is informed of the fact. The computer extracts this data on a real-time sampling basis and decides, on the basis of the input data and predetermined probabilities, whether the combatant who intercepted the laser beam should be declared "hit". If the "hit" decision is made, data is sent to the interfacing digital circuitry indicating this, and the owner of the receiver is given a 30-second audio signal informing him that he is declared dead and is out of the maneuver. For the armored vehicles, this "hit" indication is also done by means of a 30-second-long smoke emission which is made visible up to 3 miles. It should be noted that both the infantryman's and the armored vehicle's laser beam transmitters are automatically disarmed when they are declared "hit".

Both the decoding and interfacing circuitry are entirely composed of standard digital integrated circuits and are worn by an infantryman in an ammo pouch. This unit (Hippack) is 2 7/8 x 4 x 6 inches and weighs approximately $2\frac{1}{2}$ pounds.

Power for the simulator is provided by rechargeable batteries which are contained within the equipment. The batteries provide sufficient power for 12-hour missions, and are also worn by an infantryman in an ammo pouch. The battery pack is 2 3/8 x 1 1/4 x 6 inches and weight approximately $3\frac{1}{2}$ pounds.