Method for accurate multi-target discrimination and compound friend or foe identification of millimetre wave system based on laser ranging technology

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Abstract. This paper uses laser ranging technology, by multiplexing of ranging buttons, reconstruction of laser rangefinders and other equipment, and utilizing distance-based comparison methods to achieve accurate discrimination of millimetre-wave identification friend or foe systems under multi-target conditions, further improving identification reliability. The experiment proves that the method is feasible and effective.

1. Introduction
Since the beginning of the 21st century, with the large-scale application of information-based weapons and equipment, combat distance has been continuously increasing and battlefield situation changes constantly, causing mistaken attacks because of error identification from time to time. The most recent typical mistaken attack occurred in 2018. A Russian Il-20 reconnaissance aircraft flying over Syria was shot down by S-200 air defense missiles from Syrian forces. As a result, many Russian soldiers on board died. Therefore, armed equipment can effectively distinguish the attributes of enemy and friend by equipped with an identification friend or foe system, which has very important practical significance for reducing the probability of accidental injury [1]-[4].

2. Principles and problems of Millimetre wave enemy identification
Compared with the widely used centimeter wave enemy identification system [5][6], the millimeter wave beam has the advantages of strong ability to penetrate the battlefield smoke and low probability of interception. Therefore, it is particularly suitable for land battlefield environment to realize enemy identification of close-range mobile targets. The ground forces of the United States and Europe are equipped with millimeter wave enemy identification systems at present [7].

The millimeter wave enemy identification system is mainly composed of three parts: the interrogator, answering machine and identification host. After the target found, the identification host starts the interrogator to send a set of coded interrogation signals to the target. If the target is your own, the transponder receives the interrogation signal and decodes it, then controls the transponder to automatically send the coded response signal. The identification host recognizes the response signal. After decoding and discriminating, the result is transmitted to the displayer for display.

In actual use, the friend or foe identification interrogation beam will have multiple targets in the coverage area, and all will generate response actions, resulting in the problem that the target cannot be accurately discriminated.
3. Basic principles of our design
Our method is in combination with the ground maneuvering platform, using the ranging button to start the friend or foe identification. By using a method based on distance comparison, we can address the issue of accurate friend or foe identification with multiple targets. The specific principle is: The ground mobile platform reuses the ranging button of the laser range finder as the button to activate the friend or foe identification. When the ranging button is pressed, the laser range finder emits the ranging laser to the target and receives the reflected signal to calculate the distance to the target. At the same time, the interrogator sends out an interrogation millimeter wave beam covering the target. All targets in the beam will generate a response action. The distance of multiple response targets can be derived according to the response time interval. By comparing the distances generated in ranging process and identification process, we can make a second judgement for the response signal to exclude interference from other targets, and to ascertain the need to query the suspicious target's friend or foe identification attribute.

Compared with millimeter-wave friend or foe identification, laser identification has better positioning accuracy and anti-interference. Therefore, by implementing software and hardware reforming, the laser rangefinder and laser warning device equipped on the ground mobile platform can be utilized to achieve the identification mode combining laser query and millimeter-wave response. This friend or foe identification processes accord with redundant design. Thus, when the millimeter-wave interrogator fails, the laser query method is utilized to ensure the identification function.

4. Specific transformation scheme
The specific transformation scheme mainly involves the control computer, laser rangefinder and related software. Transform the laser rangefinder into a laser rangefinder/interrogator to realize the laser code interrogation function; transform the control computer and the laser power counter into a two-way information interaction channel to realize the receiving of laser pulse code information by transformed rangefinder; Modify the software of control computer to complete the function of receiving the coded information from the identification host and sending it to the laser rangefinder.

4.1. Control Computer
The transformation of the control computer mainly includes hardware and software. The hardware modification is to ensure communication with the laser rangefinder/interrogator; the software modification is to adapt to the change of communication protocol with the laser rangefinder/interrogator.

4.1.1. Hardware changes. Add the two-way communication channel on the basis of the original circuit board, and connect the corresponding pin of the external connector.

4.1.2. Software changes. Add laser query code issuance and reception, and the friend or foe identification result information under the working mode into the communication protocol; add code reception, application acceptance confirmation and other information into the communication protocol with the laser rangefinder/interrogator.

(1) Communication protocol between control computer and identification host
Add the following content: code issuance, the identification host sends laser coding information to the control computer; code reception confirmation, the control computer sends confirmation information to the identification host, including the laser code; code application, the control computer sends the coding request to the identification host after receiving the code application of the laser rangefinder; setting information of the laser coding query and the ranging working mode.

(2) Communication protocol between control computer and laser range finder
Add two-way communication interface and the protocol of code issuance and application, the specific content includes: the control computer receives the coded information from the identification host and send to the laser rangefinder; the laser rangefinder implements confirmation and response after
receiving the coded information, if the confirmation information is not received within the specified
time, it will be resent again. If the normal communication cannot be completed after responding, it
will be recorded as a communication failure.

4.2. Laser Rangefinder/Interrogator

The transformation of the control computer mainly includes hardware and software. The hardware
modification is to ensure communication with the laser rangefinder/interrogator; the software
modification is to adapt to the change of communication protocol with the laser
rangefinder/interrogator.

4.2.1. Laser. The laser is one of the core components of the laser rangefinder. In order to meet the
requirements of the continuous pulse operating frequency of the laser rangefinder/interrogator, the
laser needs to be redesigned, including the redesign of the pump source, the improvement of the
coelomic heat management system, to meet the heat dissipation requirements of continuous pulse laser.

4.2.2. Power counter. The power counter is mainly composed of a power board, a counting logic
control board, etc. The power board mainly provides working power for the laser and the laser
receiving amplifier; the counting logic control board mainly realizes the distance counting and logic
control of the laser rangefinder and its communicates with the control computer.

The focus of the power counter transformation is to redesign the power board and counting logic
control board to meet the requirements of continuous pulse operating frequency laser
rangefinder/interrogator. Modification of power board: transform the power board of the laser range
finder from single-pulse working frequency power board to continuous pulse working frequency
power board; transformation of the logic control board: transform the counting logic control board of
the laser range finder from control board only for range counting and logic control to a control board
for range counting, query coding, and logic control; the interface of the laser range finder and the
original control computer interface remains unchanged.

4.3. Laser alarm

The laser alarm is transformed into a laser alarm/receiver, which realizes the function of identifying
the laser interrogation code. The specific scheme is to add the query code issuance and application
information on the basis of the original communication protocol between the laser alarm/receiver and
the identification host; after receiving the laser query code, the trigger response message is sent to the
identification host; For the laser alarm to send to the identification host, add the laser alarm request
code, the indicating code of correct receiving, etc.

4.4. Design of the friend or foe identification process

4.4.1. Inquiry process. When performing laser ranging, the laser rangefinder/interrogator sends a laser
query code. The other side’s laser alarm receives and reports it, and its recognizer sends out a response
message. When the interrogator sends the laser query, the control computer sends the start query
command to the identification host. Then the identification host starts the entire identification process;
after starting the query command, the control computer transmits the laser ranging distance
information to the identification host; after receiving the distance information, the identification host
matches the query target; and starting with the query command, the identification host reports the
matching target attribute information, multi-target information, etc. to the control computer and
display control terminal within the specified time.

4.4.2. Response process. After receiving the query millimetre wave information, the millimetre wave
transponder discriminates the query information; if it is a query from a friend, it sends a response code
through the millimetre wave transponder and reports the millimetre wave information being queried.
After receiving the laser query signal, the laser alarm/receiver sends a start response command to the millimetre wave transponder, and the millimetre wave transponder sends a response code matching the laser query.

4.4.3. Friend or foe identification timing. After the start signal of ranging is triggered, the laser interrogation launch equipment and the millimetre-wave friend or foe identification system send interrogation commands respectively.

The millimetre-wave friend or foe identification system issues an inquiry and starts timing, with the starting time of the inquiry as the starting point. After receiving this signal, the responder of the millimetre wave friend or foe identification system performs a normal millimetre-wave query and response to judge whether the received millimetre-wave query signal has a laser query.

The laser rangefinder sends an inquiry command. After receiving the laser inquiry command, the laser alarm tells the millimetre-wave transponder to respond to the laser inquiry through the identification host. After the complement of normal millimetre-wave interrogation and response sequence, the millimetre-wave response information for the laser query is directed at the appointed time.

5. Experiment

5.1. Multi-pattern identification probability test
The ground mobile platform A is equipped with interrogation equipment, and the ground mobile platform B is equipped with answering equipment. The two platforms are successively tested at three distances: near, medium, and far. Among them, the millimeter wave query response identification probability is tested by manual single operation (20 times) and automatic continuous operation (200 times), and the laser query/millimeter wave response identification probability is tested by manual single operation (20 times). The result of multi-pattern identification probability test is shown in table 1.

| number | mode | distance | correct/total number | Identification probability |
|--------|------|----------|----------------------|----------------------------|
| 1      | Millimetre wave query response (automatic continuous) | near | 200/200 | 100% |
|        |       | medium   | 200/200 | 100% |
|        |       | far      | 200/200 | 100% |
| 2      | Millimetre wave query response (manual single) | near | 20/20 | 100% |
|        |       | medium   | 20/20 | 100% |
|        |       | far      | 18/20 | 90% |
| 3      | laser query/millimeter wave response (manual single) | near | 20/20 | 100% |
|        |       | medium   | 20/20 | 100% |
|        |       | far      | 18/20 | 90% |

5.2. Multi-target identification probability test
The ground mobile platform A is equipped with interrogation equipment, and the ground mobile platforms B, C, and D are equipped with answering equipment. The four platforms are distributed in sequence and are on the same straight line. Distances from B, C and D to A are respectively near, medium and far. For B, C and D, A respectively performs manual single millimeter wave inquiry for 20 times. Multi-target response test result is shown in table 2.
Table 2. Result of multi-target response test.

| number | mode                        | distance | correct/total number | Identification probability |
|--------|-----------------------------|----------|----------------------|---------------------------|
| 1      | Millimetre wave query       | near     | 18/20                | 90%                       |
| 1      | Identification probability  | medium   | 20/20                | 100%                      |
| 1      | Identification probability  | far      | 19/20                | 95%                       |

6. Conclusion
By using laser ranging technology, the laser rangefinder and laser alarm device can be properly modified to solve the problem of the misjudgment of the millimeter-wave friend or foe identification system in the case of multi-targets. At the same time, the redundant design of friend or foe identification is achieved, which improves the reliability of identification. It has been verified by experiments that the system has a relatively high identification probability in multiple modes and the ability to accurately discriminate multiple targets.

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