Research on Test Method of Smart Anti-Towed Radar Active Decoy in Complex Electromagnetic Environment

Bo Zhao*, Duo Wang
Army92941, Liao Ning Hu Lu-dao, China

*Corresponding author: 20150731@qq.com

Abstract. As an effective jamming method, towed radar active decoy, poses a great threat to monopulse radar seekers, and has attracted more and more attention from various countries. This article analyzes the interference mechanism and main parameters of towed radar active decoys, and provides a theoretical basis for the use of towed decoys. In view of its technical characteristics, combined with technical and tactical countermeasure strategies and technical approaches, research the test range to carry out countermeasures against towed radar active decoys, and provide theoretical basis and reference value for the use of towed radar active decoy countermeasures in the range.

Keywords: TRAD, countermeasure technology, equivalent interference power, test method.

1. Introduction
The continuous development of precision-guided weapons makes it occupy an increasingly important position in modern warfare. The accompanying countermeasure technology is also changing with each passing day. Electronic countermeasures technology in complex electromagnetic environments is playing an increasingly important role in modern warfare. The assessment of new missile weapons has also entered the stage of interference countermeasures, but there is currently no assessment of towed radar active decoys. Towed radar active decoys (TRAD) are designed to counter the interference generated by monopulse radar seekers. Style [1] is a new way of self-defense interference [2]. TRAD is mainly used for the protection of airborne platforms. It is connected to the carrier aircraft through a towing line, and is within the instantaneous beam range of the radar seeker together with the carrier aircraft, forming dual point source interference. Since the decoy can simulate the speed, heading and radar reflection characteristics of the carrier, the current general radar seeker cannot distinguish between the target and the decoy by the motion characteristics [3]. In the Kosovo War, the US military used towed radar active decoys to successfully deceive 10 enemy air defense missiles [4-6]. The existence of towed decoys greatly improved the survivability of the carrier [7]. Based on the analysis of the jamming mechanism of the towed radar active decoy, combined with its countermeasure technology, this article conducts research on the anti-jamming test method of the shooting range.
2. Technical characteristics of TRAD

2.1. Interference mechanism
The main function of TRAD is to protect the carrier platform when the carrier is threatened by missiles. It is a kind of active interference outside the carrier. When an aircraft encounters an incoming missile, the carrier launches a decoy, and the decoy is configured with the carrier through the towing line. The radar receiver on the carrier receives the incoming missile radar seeker signal and analyzes the radar signal parameter information. The line control decoy transmits an interference signal similar to the echo of the carrier in a forwarding or response mode, and forms a dual-point source interference with the radar echo reflected by the carrier, as shown in Figure 1. At the same time, the carrier releases the bait and then maneuvers to form an angle. Deception, and ready to escape the seeker radar beam range at any time. The principle of TRAD interference is the same as that of the two-point source jamming monopulse radar. Based on the seeker tracking radar, the two radio frequency signals in the same beam cannot be distinguished from the angle, so that it cannot accurately strike the target.

![Figure 1. Schematic diagram of TRAD](image)

2.2. Interference process
From the perspective of the spatial position relationship between the target and the interference, the towed decoy interference belongs to the interference outside the carrier. By separating the jammer and the target, it can effectively interfere with the radar's angle tracking system and deceive the radar to misguide, thereby protecting the safety of the carrier. TRAD interference goes through the following stages in the release process:

(1) The warning system on the carrier aircraft (target) indicates that it is irradiated by the radar, and the towed decoy is released. The decoy receives the radar signal, and generates and transmits the interference signal according to the interference logic. At this time, the distance between the decoy and the target is very small, and the interference signal will be easier to capture the radar tracking gate, effectively "attracting" the radar beam to illuminate.

(2) After capturing the wave gate, the target forms an interference triangle situation between the target, decoy and radar through maneuvering. On the one hand, the purpose of maneuvering is to avoid the cone-shaped blind area formed by the target's occlusion of the decoy; on the other hand, it is to increase the angular distance between the target and the decoy and form a better angle deception for the radar.

(3) As the maneuver progresses and the distance between the radar and the target, the radar and the decoy approaches, the opening angle between the target and the decoy gradually increases. Since the power of the interference signal is much greater than the power of the target echo signal, the center of the radar beam will be biased toward the decoy, causing the target to gradually move to the edge of the radar beam.

(4) With the further reduction of the distance between the radar and the target, the radar and the decoy, when the opening angle between the target and the decoy increases to a certain extent, the
target will escape the radar beam irradiation range, and only the decoy will exist in the beam, The radar completely lost the target.

2.3. Design principles

The main task of TRAD is to interfere with the angle measurement system of the monopulse radar seeker and cause the angle tracking system of the seeker to produce angle measurement deviation. According to this, the towed radar active decoy is designed to affect the length of the tow line and the decoy equivalent interference power has certain principles and requirements.

(1) Drag line length

The towed bait is connected to the carrier through a towing line, and the length of the towing line directly affects the success or failure of the bait interference. In the process of design and actual use, the length of the towing line should be selected according to the missile’s kill radius, seeker tracking characteristics, and decoy equivalent interference power. If the equivalent interference power of the decoy is the same as the energy of the carrier’s echo, the missile tracking point is at the middle of the two, and the towing line length should be greater than twice the missile’s kill radius; if the decoy’s equivalent interference power is greater than the carrier’s echo energy, the tracking point of the seeker is biased towards the bait, and the length of the towing line can be appropriately shortened at this time. However, the seeker angle tracking system limits the maximum horizontal and longitudinal distance of the decoy relative to the carrier. If the limit is exceeded, the decoy and the carrier are not in the same angle resolution unit of the radar seeker, and the seeker can move from The decoy and the carrier are identified in azimuth and distance, so the towing line should not be too long. The air situation of the carrier, decoy and missile is shown in Figure 2.

\[
AB = L \times \sin(\alpha - \theta)
\]

Since the beam of the radar seeker is generally small, \(AB = L \times \sin(\alpha - \theta) = R \times \theta\), then the upper limit of the drag line length can be obtained as

\[
L = R \times \theta / \sin(\alpha - \theta)
\]

Where R is the distance from the missile to the decoy.

In practice, it is also necessary to consider the distinguishable area of the angle between the carrier and the decoy and the maneuvering factors of the carrier. Usually, the length of the towing line of the transport aircraft is 90m~120m, and the length of the fighter aircraft is about 100m [8].

(2) Equivalent interference power
After the towed decoy is released, the tracking point of the missile is located at the center of mass of the line connecting the two under the condition of double-point source interference. In order to make the center of mass aimed at by the missile closer to the decoy, the interference power of the decoy is required to be greater than the echo power of the target. That is, the dry-to-signal ratio is greater than 1, which is generally 3~10 according to current research.

(3) Interfering radio frequency emission method

Towed decoy interference undergoes three stages in the release process: suppression interference, deception interference and decoy interference. In the suppression of interference at the initial stage of decoy release, the radio frequency signal with higher power than the radar seeker signal is used to suppress the seeker radar signal from the power, so that the seeker cannot detect normally; after the missile turns to track the suppressed signal According to the intercepted seeker radar radio frequency signal parameters, the carrier aircraft transmits it to the towed decoy, and forwards the same radio frequency signal to form deceptive interference to the missile; after the decoy is released, it forms a dual-point source interference with the carrier aircraft to deceive the seeker The tracking position enables it to track the energy centroid of the carrier and the decoy, and try to be biased towards the position of the decoy. The carrier is maneuvering and is always ready to leave the range of missile attack.

3. Typical confrontation techniques and tactics

3.1. Technical improvement of radar seeker
(1) Improve radar range resolution

In order to effectively improve the transmission and reception isolation problem and reduce the mass and volume of the decoy, the receiving system and the launching system of the towed radar active decoy are located on the carrier and the decoy respectively. Due to the different signal transmission process, the decoy interferes between the signal and the carrier’s echo. There is a certain time delay, as shown in figure 3.

\[ \Delta t = \frac{R_d + R_2 - R_1}{c} \]  

Accordingly, in the countermeasure technology, the range resolution of the radar signal can be improved to counter the decoy, and the PD system radar seeker can use pulse compression technology to improve the range resolution. After adopting the pulse compression technology for the launch pulse of the seeker, the distance resolution can be effectively improved under the premise that the average launch power is guaranteed, thereby enhancing the seeker's ability to sort dual targets in the distance. When the carrier and the bait are in different distance discrimination units, the chirp signal is used to separate the difference in distance between the carrier and the bait, and the seeker can distinguish between the two.
(2) Improve radar speed and angle resolution

After the towed decoy is released, it is dragged and flew by the carrier. The two have almost the same motion characteristics. At long distances, the decoy and the target are in the half-power beam width of the radar, so it is easy to deceive in terms of speed and angle. However, due to the existence of the towing line, there is always a slight difference in speed and distance between the decoy and the carrier. The high-resolution radar is used to separate the small difference between the carrier and the decoy by improving the range and speed resolution of the radar signal. For example, the use of chirp signals and phase-encoded pulse compression signals to achieve the purpose of identifying targets.

3.2. Anti-jamming analysis of compound guidance technology

The compound guidance technology can give full play to the advantages of each seeker, and has a stronger ability to accurately track and anti-jamming. According to the technical characteristics of towed jamming, the combined guidance of radar seeker and infrared seeker is used to give full play to their respective advantages. When the relative distance of the missile and the target enters the infrared detection range, it is convenient to use the real-time background image model. The threshold detection method is used to extract the target signal, and the required line-of-sight error signal is given, and the infrared seeker can track the target stably. Since the interference formed by the bait and the carrier aircraft cannot deceive the infrared seeker, the infrared seeker can track the carrier aircraft more accurately. While the infrared seeker is tracking the target, the main beam of the radar seeker is adjusted to point to the carrier, so that the radar seeker can track the position of the carrier. After the radar seeker and infrared seeker track the target, the radar and infrared measurement data are sent to the data fusion center in real time for fusion processing, and the fusion tracking data is output to control the missile to fly to the target. As the distance between the projectile and the target decreases, when the opening angle formed by the carrier aircraft and the decoy relative to the radar seeker reaches a critical angle, the radar seeker will select the carrier aircraft for precise tracking.

4. Design of anti-TRAD test

The anti-TRAD test can be carried out by a combination of simulation test, follow-up test and flight test.

(1) Simulation test method

The anti-jamming simulation test of the seeker uses the target simulation equipment to simulate the target echo; the interference simulation equipment simulates the real-time changes of the interference signal, and the interference parameters are set according to the typical interference environment; the data acquisition computer is used to collect the output information of the seeker in real time and participate in the missile. Real-time calculation of the simulation model; the ballistic calculation computer combines the test situation information to calculate the real-time ballistic simulation model, and according to the calculation information, the nodes are controlled to run synchronously in the frame period in real time; the three-axis turntable simulates the missile attitude angle after coordinate transformation changes; the data acquisition equipment records the output data information of each node of the system in real time for the application of test data analysis and processing. The simulation test can be repeated many times under the premise of low efficiency and cost ratio, and the adjustment and control of various parameters are convenient, and it is easy to traverse different interference patterns and methods.

(2) Follow-up test method

The follow-up test can be carried out separately or in combination with the flight test. During follow-up, the missile (seeker) is set up at a high altitude or on a ship-borne test platform. The target aircraft is equipped with interference equipment to enter from a long distance, and the missile is guided by the target system. Provide information or pre-align the target's entry direction to search and intercept the target; the jamming equipment will release the jam according to the predetermined plan; the target aircraft will turn to re-enter after passing the top, and each entry will be a voyage; the data recording equipment will record the missile and jamming equipment related data information.
According to the technical state of the jamming equipment, different jamming patterns are used for each entry. Generally, 2 to 3 voyages are carried out for each jamming pattern.

In the test, the use of towed interference needs to pay attention to (a) the timing of bait release. When the decoy is released, it should be ensured that the angle formed by the aircraft and the decoy on the radar is smaller than the angular resolution of the radar. In terms of distance, it should be ensured that the distance difference between the aircraft and the decoy to the radar is less than the range resolution of the radar. In terms of speed, it should be ensured that the radial velocity difference between the aircraft and the decoy relative to the radar is less than the speed resolution of the radar. (b) Length of line. The selection of the towing line length L must first ensure that the distance between the decoy and the carrier is far enough. When the missile explodes between the decoy and the carrier, it will not damage the carrier, which is generally greater than twice the effective killing radius of the missile. The angle tracking system puts a limit on the maximum lateral distance of the decoy relative to the carrier, and the range tracking of the radar puts a limit on the maximum longitudinal distance of the decoy relative to the carrier.

(3) Flight test method

Flight test is the most costly test method, and only one sample can be obtained at a time. Interference environment construction equipment includes targets, missile-borne or airborne active decoy jamming equipment. Target missiles or drones are loaded with active decoy jammers to implement noise and deception jamming. The jamming parameters are set according to the typical jamming parameters.

5. Conclusion

TRAD is a new type of jamming developed for monopulse radars. It is a key technical problem to be solved urgently for radar seekers of the current PD system, and the technical difficulty of countermeasures is relatively high. Based on the analysis of the interference mechanism of active towed decoys, this paper studies the direct influence of the towed decoy on the seeker radar signal, and combines the typical technical and tactical countermeasure mechanism to carry out the experimental design of the anti-towed radar active decoy. The effective countermeasure of towed radar active decoy provides a theoretical basis, and has reference value for the appraisal of the range test.

References

[1] William J Kerins. Analysis of Towed Decoys [J]. IEEE Transaction on Aerospace and Electronic Systems (S0018-9251), 1993, 29(4): 1222-1227.
[2] Nong Chun-li. Research and simulation of airborne towed radar active decoy countermeasures [J] Electronic Science and Technology. 2011 (7), 24 (7): 42-44.
[3] Chen Yi, Cui Yan-peng, Zhong Zhao. Discussion on the interference style of active towed decoy, namely countermeasures [J] Aerospace Electronic Warfare. 2011 (5), 27 (5): 10-12
[4] Dong Hui-xu, Bai Wei-xiong, Li Dong-wei, etc. Research on towed decoy countermeasures [J]. Flying Missile, 2011 (6): 91-95.
[5] Bai Wei-xiong, Tang Hong, Tao Jian-feng. Interference analysis of towed decoy on monopulse radar [J]. Electronic Information Warfare Technology, 2007, 11 (6): 39-42.
[6] Hou Xiang-hui, Liu Xiao-dong, Li Xian-mao. Discussion on towed decoys to deceive air defense missiles [J]. Ship Electronic Warfare, 2010, 33 (1): 40-43.
[7] Fang You-pei. Research on towed active radio frequency decoy jamming prevention and control missiles [J] Aerospace Electronic Warfare, 2001 (4): 16-19.
[8] Bai Wei-xiong, Jiao Guang-long, Fu Hong-wei. Research on towed decoy countermeasure technology [J]. Systems Engineering and Electronic Technology, 2009, 31(3): 580-582.