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Evaluation Method of Formation Ship-to-air Missile Air Defense Area Capability

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Abstract

Aiming at the problem of evaluating formation ship-to-air missile air defense area capability based on azimuth formation and herringbone formation, an evaluation method of formation ship-to-air missile air defense area capability was proposed, which can evaluate the formation ship-to-air missile air defense area capability indexes such as the maximum intercepting target times and the missile consumption, and provide a method basis for the formation ship-to-air missile air defense area capability evaluation.

Keywords

Formation; Ship-to-air Missile; Air Defense; Area Capability.

1. Introduction

When the ship-to-air missile weapon of the ship formation intercepts aerial targets, the formation ship-to-air missile air defense area capability evaluation can be studied. Prior methods, such as comprehensive analysis method [1-14], index method [15-17], simulation method [18-20], are primarily used for assessing ship-to-air missile air defense capability evaluation of single ship-to-air missile system. The factors such as area capability and formation type aren't considered by the above methods.

A method for evaluating the formation ship-to-air missile air defense area capability is proposed in this paper, which can be used to evaluate the formation ship-to-air missile air defense capability indexes such as the maximum intercepting target times and ship-to-air missile consumption, which provides a method and basis for the formation ship-to-air missile air defense area capability evaluation.

2. Evaluation Method of Formation Ship-to-Air Missile Air Defense Area Capability based on Azimuth Formation

As shown in Figure 1, it is assumed that the distance values of the ship-to-air missile horizontal plane launch areas of ships A_{f1}, A_{f2}, A_{f3} are all R_f. The Y_{f1} circle, the Y_{f2} circle, and the Y_{f3} circle are the ship-to-air missile horizontal plane launch areas of ships A_{f1}, A_{f2}, A_{f3} respectively. They are circles with the positions of ships A_{f1}, A_{f2}, A_{f3} as the center and the distance R_f as the radius. The intersections of the Y_{f1} circle and the Y_{f2} circle are points B_{f1} and B_{f2}, the intersections of the Y_{f2} circle and the Y_{f3} circle are points B_{f3} and B_{f4}, the intersections of the Y_{f1} circle and the array line are points C_{f1} and C_{f4}, the intersections of the Y_{f2} circle and the array line are points C_{f2} and C_{f5}, and the intersections of the Y_{f3} circle and the array line are points C_{f3} and C_{f6}.

In Figure 1. This paper mainly discusses the calculation of maximum intercepting target times defined by W_{fc} and maximum intercepting target missile consumption defined by W_{fd} when the target attacks in the ship-to-air missile cooperative horizontal launch area, a horizontal area composed of an arc segment $\overset{\frown}{B_{f3}C_{f5}B_{f4}}$ and a straight segment $B_{f3}B_{f4}$ of two adjacent ships, ship

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A_{f2} and ship A_{f3}. It is assumed that the target flies toward the ship A_{f2} at a constant speed in a straight line, and the angle between the target attack direction and the horizontal line is also a.

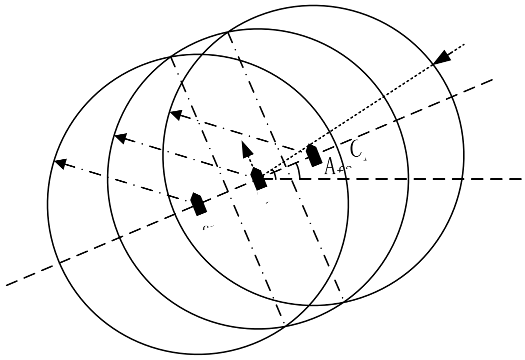

Figure 1. Azimuth formation

2.1. shoot-look-shoot (SLS)

Assume that the ship-to-air missile target encounter distance is S_{wd1} when the first ship-to-air missile launched by the ship intercepts the target. Suppose the reaction time of the ship-to-air missile weapon system is T_{fy}, the target speed is V_m, and the average speed of the ship-to-air missile is V_d. The calculation formula for S_{wd1} is in equation (1).

$$S_{wd1}=R_f-T_{fy}V_m-V_m[(R_f-T_{fy}V_m)/(V_m+V_d)] \quad (1)$$

The S_{wd1} value is valid when $S_{wd1}\geq|A_{f2}D_{f2}|$, and subsequent calculations are performed. The S_{wd1} value is invalid when $S_{wd1}<|A_{f2}D_{f2}|$, and no further calculations are performed.

Assume that the ship-to-air missile target encounter distance when the second ship-to-air missile launched by the ship intercepts the target is S_{wd2}, and the average time of ship-to-air missile damage effect evaluation is T_g, the launch time of ship-to-air missile system is T_b. The calculation formula for S_{wd2} is in equation (2).

$$S_{wd2}=S_{wd1}-T_gV_m-T_bV_m-V_m[(S_{wd1}-T_gV_m-T_bV_m)/(V_m+V_d)] \quad (2)$$

The S_{wd2} value is valid when $S_{wd2}\geq|A_{f2}D_{f2}|$, and subsequent calculations are performed. The S_{wd2} value is invalid when $S_{wd2}<|A_{f2}D_{f2}|$, and no further calculations are performed.

Assume that the ship-to-air missile target encounter distance when the third ship-to-air missile launched by the ship intercepts the target is S_{wd3}. The calculation formula for S_{wd3} is in equation (3).

$$S_{wd3}=S_{wd2}-T_gV_m-T_bV_m-V_m[(S_{wd2}-T_gV_m-T_bV_m)/(V_m+V_d)] \quad (3)$$

The S_{wd3} value is valid when $S_{wd3}\geq|A_{f2}D_{f2}|$, and subsequent calculations are performed. The S_{wd3} value is invalid when $S_{wd3}<|A_{f2}D_{f2}|$, and no further calculations are performed.

By analogy, assume that the ship-to-air missile target encounter distance is S_{wdN} when the N_{f1}th ship-to-air missile launched by the ship for the N_{f1}th time intercepts the target. Finally, when $S_{wdN}<|A_{f2}D_{f2}|$, the S_{wdN} value is invalid and the calculation is terminated. At this time, $W_{fc}=N_{f1}-1$ and $W_{fd}=N_{f1}-1$ are obtained.

2.2. shoot-shoot-look-shoot-shoot (SSLSS)

Calculation of the ship-to-air missile target encounter distance when the two missiles launched by the ship intercept the target for the first time. Among the two ship-to-air missiles this time, assume that the ship-to-air missile target encounter distance is S_{wd11} when the first ship-to-air missile intercepts the target. The calculation formula for S_{wd11} is in equation (4).

$$S_{wd11}=R_f-T_{fy}V_m-V_m[(R_f-T_{fy}V_m)/(V_m+V_d)] \quad (4)$$

The S_{wd11} value is valid when $S_{wd11} \geq |A_{f2}D_{f2}|$, and subsequent calculations are performed. The S_{wd11} value is invalid when $S_{wd11} < |A_{f2}D_{f2}|$, and no further calculations are performed.

Among the two ship-to-air missiles, assume that the ship-to-air missile target encounter distance is S_{wd12} when the second ship-to-air missile intercepts the target. Assume that the ship-to-air missile launch interval is T_j, the S_{wd12} calculation formula is in equation (5).

$$S_{wd12}=S_{wd11}-T_jV_m \tag{5}$$

The S_{wd12} value is valid when $S_{wd12} \geq |A_{f2}D_{f2}|$, and subsequent calculations are performed. The S_{wd12} value is invalid when $S_{wd12} < |A_{f2}D_{f2}|$, and no further calculations are performed.

Calculation of the ship-to-air missile target encounter distance when the two missiles launched by the ship for the second time intercept the target. Among the two ship-to-air missiles this time, assume that the ship-to-air missile target encounter distance is S_{wd21} when the first ship-to-air missile intercepts the target. The calculation formula for S_{wd21} is in equation (6).

$$S_{wd21}=S_{wd12}-T_gV_m-T_bV_m-V_m[(S_{wd12}-T_gV_m-T_bV_m)/(V_m+V_d)] \tag{6}$$

The S_{wd21} value is valid when $S_{wd21} \geq |A_{f2}D_{f2}|$, and subsequent calculations are performed. The S_{wd12} value is invalid when $S_{wd21} < |A_{f2}D_{f2}|$, and no further calculations are performed.

Among the two ship-to-air missiles, assume that the ship-to-air missile target encounter distance is S_{wd22} when the second ship-to-air missile intercepts the target. The calculation formula for S_{wd22} is in equation (7).

$$S_{wd22}=S_{wd21}-T_jV_m \tag{7}$$

The S_{wd22} value is valid when $S_{wd22} \geq |A_{f2}D_{f2}|$, and subsequent calculations are performed. The S_{wd22} value is invalid when $S_{wd22} < |A_{f2}D_{f2}$, and no further calculations are performed.

By analogy, calculate the ship-to-air missile target encounter distance when the two ship-to-air missiles launched by the ship for the N_{f2}th time intercepting the target. Among the two ship-to-air missiles, assume that the ship-to-air missile target encounter distance is S_{wdN11} when the first ship-to-air missile intercepts the target, and the missile target encounter distance is S_{wdN12} when the second ship-to-air missile intercepting the target. S_{wdN11} and S_{wdN12} are calculated in the same way. First, if the value of S_{wdN11} is invalid when $S_{wdN11} < |A_{f2}D_{f2}|$, the subsequent calculation of S_{wdN12} is not performed, and $W_{fc}=N_{f2}-1$ and $W_{fd}=2(N_{f2}-1)$ are obtained at this time. Second, if $S_{wdN11} \geq |A_{f2}D_{f2}|$ and $S_{wdN12} < |A_{f2}D_{f2}|$, the S_{wdN12} value is invalid, and the calculation is terminated. At this time, $W_{fc}=N_{f2}$, $W_{fd}=2(N_{f2}-1)+1$ is obtained.

3. Evaluation Method of Ship-to-Air Missile Air Defense Area Capability based on Herringbone Formation

As shown in Figure 2. Assume that the distance values of the ships A_{r1}, A_{r2}, A_{r3} and A_{r4} to the far end of the ship-to-air missile horizontal launch area are R_r, the straight lines $A_{r1}J_{r1}$ and $A_{r1}J_{r2}$ are the angle lines of the queue, and the straight line $A_{r1}J_{r3}$ is the center line. The Y_{r1} circle, the Y_{r2} circle, the Y_{r3} circle, and the Y_{r4} circle are the ship-to-air missile horizontal launch areas of the ships A_{r1}, A_{r2}, A_{r3} and A_{r4} respectively. They are circles with the positions of the ships A_{r1}, A_{r2}, A_{r3}, A_{r4} as the centers and the distance R_r of the ship-to-air missile horizontal launch areas of these ships as the radius. The intersections of the straight line $A_{r1}J_{r3}$ and the circle Y_{r1} are points B_{r1} and B_{r4}, the intersections of the straight line $A_{r1}J_{r3}$ and the circle Y_{r2} are points B_{r2} and B_{r5}, the intersections of the straight line $A_{r1}J_{r3}$ and the circle Y_{r3} are points B_{r3} and B_{r6}, and the intersections of the straight line $A_{r1}J_{r3}$ and the circle Y_{r4} are points E_{r1} and E_{r2}. The intersections of Y_{r1} circle and Y_{r2} circle are point D_{r1} and point C_{r3}, the intersections of Y_{r2} circle and Y_{r3} circle are point C_{r1} and point D_{r3}, the intersections of Y_{r1} circle and Y_{r3} circle are point C_{r2} and point D_{r3}, the intersections of Y_{r1} circle and Y_{r4} circle are point C_{r5} and point D_{r4}, and the intersections of Y_{r3} circle and Y_{r4} circle are point C_{r4} and point D_{r6}.

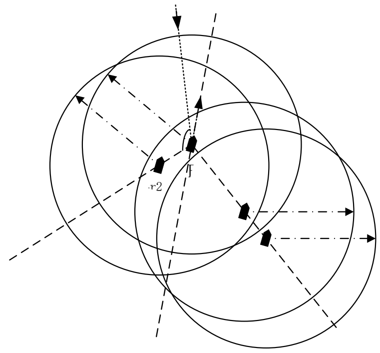

Figure 2. Herringbone formation

In Figure 2. This paper discusses the calculation of the maximum intercepting target times defined by W_{rc} and the maximum intercepting target missile consumption defined by W_{rd} when the target attacks in the ship-to-air missile cooperative horizontal plane launch area, a horizontal area composed of the arc segment $\overset{\frown}{B_{r2}D_{r1}D_{r2}D_{r4}B_{r4}}$ and the straight segment $B_{r2}B_{r4}$ of two adjacent ships, ship A_{r1} and ship A_{r2}. It is assumed that the target is flying toward the ship A_{r1} in a constant speed straight-line flight. The included angle of the target's attack direction and the reference ship's port side queue angle line $A_{r1}J_{r1}$ is C, and the intersection point of the target's attack direction line and the arc segment $\overset{\frown}{B_{r2}D_{r1}D_{r2}D_{r4}B_{r4}}$ is point F_{r1}. Let the ship spacing between two adjacent ships, the ship A_{r1} and the ship A_{r2}, be L_{r1}.

Assume that the minimum distance is S_{xmin} when the ship-to-air missile system intercepts the target. Assume that the near boundary distance of the kill zone of the ship-to-air missile is S_{min}, the S_{xmin} calculation formula is in equation (8).

$$S_{xmin}=S_{min}+T_{fy}V_m+V_m[S_{min}/(V_m+V_d)] \tag{8}$$

3.1. Shoot-look-shoot (SLS)

Assume that the ship-to-air missile target encounter distance is S_{rz1} when the first ship-to-air missile launched by the ship intercepts the target. In equation (9), S_{rz1} is calculated.

$$S_{rz1}=|A_{r1}F_{r1}|-T_{fy}V_m-V_m[(|A_{r1}F_{r1}|-T_{fy}V_m)/(V_m+V_d)] \tag{9}$$

The S_{rz1} value is valid when $S_{rz1}\geq S_{xmin}$, and subsequent calculations are performed. The S_{rz1} value is invalid when $S_{rz1}<S_{xmin}$, and no further calculations are performed.

Assume that the ship-to-air missile target encounter distance is S_{rz2} when the second ship-to-air missile launched by the ship intercepts the target. In equation (10), S_{rz2} is calculated.

$$S_{rz2}=S_{rz1}-T_gV_m-T_bV_m-V_m[(S_{rz1}-T_gV_m-T_bV_m)/(V_m+V_d)] \tag{10}$$

The S_{rz2} value is valid when $S_{rz2}\geq S_{xmin}$, and subsequent calculations are performed. The S_{rz2} value is invalid when $S_{rz2}<S_{xmin}$, and no further calculations are performed.

Assume that the ship-to-air missile target encounter distance is S_{rz3} when the third ship-to-air missile launched by the ship intercepts the target. In equation (11), S_{rz3} is calculated.

$$S_{rz3}=S_{rz2}-T_gV_m-T_bV_m- V_m[(S_{rz2}-T_gV_m-T_bV_m)/(V_m+V_d)] \tag{11}$$

The S_{rz3} value is valid when $S_{rz3}\geq S_{xmin}$, and subsequent calculations are performed. The S_{rz3} value is invalid when $S_{rz3}<S_{xmin}$, and no further calculations are performed.

By analogy, calculate the missile target encounter distance (S_{rzN}) when the N_{r1}st ship-to-air missile launched by the ship for the N_{r1}th time intercepting the target. Finally, when $S_{rzN}<S_{xmin}$, the S_{rzN} value is invalid and the calculation is terminated. At this time, $W_{rc}=N_{r1}-1$ and $W_{rd}=N_{r1}-1$ are obtained.

3.2. shoot-shoot-look-shoot-shoot (SSLSS)

Calculation of the missile target encounter distance when the two missiles launched by the ship intercepted the target for the first time. Among the two ship-to-air missiles this time, assume that the ship-to-air missile target encounter distance is S_{rz11} when the first ship-to-air missile intercepts the target. The calculation formula for S_{rz11} is in equation (12).

$$S_{rz11}=|A_{r1}F_{r1}|-T_{fy}V_m-V_m[(|A_{r1}F_{r1}|-T_{fy}V_m)/(V_m+V_d)] \quad (12)$$

The S_{rz11} value is valid when $S_{rz11}\geq S_{xmin}$, and subsequent calculations are performed. The S_{rz11} value is invalid when $S_{rz11}<S_{xmin}$, and no further calculations are performed.

Among the two ship-to-air missiles, assume that the missile target encounter distance isS_{rz12} when the second ship-to-air missile intercepts the target. The calculation formula for S_{rz12} is in equation (13).

$$S_{rz12}=S_{rz11}-T_jV_m \quad (13)$$

The S_{rz12} value is valid when $S_{rz12}\geq S_{xmin}$, and subsequent calculations are performed. The S_{rz12} value is invalid when $S_{rz12}<S_{xmin}$, and no further calculations are performed.

Calculation of the missile target encounter distance when the two missiles launched by the ship for the second time intercept the target. Among the two ship-to-air missiles this time, assume that the ship-to-air missile target encounter distance is S_{rz21} when the first ship-to-air missile intercepts the target. The calculation formula for S_{rz21} is in equation (14).

$$S_{rz21}=S_{rz12}-T_gV_m-T_bV_m-V_m[(S_{rz12}-T_gV_m-T_bV_m)/(V_m+V_d)] \quad (14)$$

The S_{rz21} value is valid when $S_{rz21}\geq S_{xmin}$, and subsequent calculations are performed. The S_{rz21} value is invalid when $S_{rz21}<S_{xmin}$, and no further calculations are performed.

Among the two ship-to-air missiles, assume that the ship-to-air missile target encounter distance is S_{rz22} when the second ship-to-air missile intercepts the target. The calculation formula for S_{rz22} is in equation (15).

$$S_{rz22}=S_{rz21}-T_jV_m \quad (15)$$

The S_{rz22} value is valid when $S_{rz22}\geq S_{xmin}$, and subsequent calculations are performed. The S_{rz22} value is invalid when $S_{rz22}<S_{xmin}$, and no further calculations are performed.

By analogy, calculate the ship-to-air missile target encounter distance when the two ship-to-air missiles launched by the ship N_{r2} intercepted the target. Among the two ship-to-air missiles this time, assume that the ship-to-air missile target encounter distance is S_{rzN11} when the first ship-to-air missile intercepts the target, and the ship-to-air missile target encounter distance is S_{rzN12} when the second ship-to-air missile intercepts the target. S_{rzN11} and S_{rzN12} are calculated in the same way. First, if S_{rzN11} is less than S_{xmin}, the value of S_{rzN11} is invalid, and the subsequent calculation of S_{rzN12} is not performed. At this time, $W_{rc}=N_{r2}-1$ and $W_{rd}=2(N_{r2}-1)$ are obtained. Second, if $S_{rzN11}\geq S_{xmin}$, and when $S_{rzN12}<S_{xmin}$, the S_{rzN12} value is invalid, and the calculation is terminated. At this time, $W_{rc}=N_{r2}$, $W_{rd}=2(N_{r2}-1)+1$ is obtained.

4. Conclusion

When evaluating the formation ship-to-air missile air defense area capability, the formation ship-to-air missile air defense capability indexes such as the maximum intercepting target times and the ship-to-air missile consumption are evaluated, which provides a method and basis for the formation ship-to-air missile air defense area capability evaluation.

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