Maneuvering Calculation of Ship Centroid Jamming

Weidong Sun

Operation Software and Simulation Institute, Dalian Naval Academy, Dalian 116018, China

570336266@qq.com

Keywords: Centroid jamming; Ship maneuver; Calculation

Abstract: According to the basic principle of centroid jamming, the basic conditions for the success of centroid jamming are analyzed, and it is pointed out that reasonable ship maneuver is the key to ensure the effect of centroid jamming. According to the basic process of centroid jamming, the ship maneuver model of centroid jamming is established, and the validity of the model is verified by simulation analysis. The established ship maneuver model transforms the complex command decision into a quantitative calculation method, which provides a reliable guarantee for the commander to make quick and accurate maneuvering decisions under various circumstances.

1. Introduction

The chaff centroid jamming refers to the fact that after the missile terminal guidance radar has tracked the target, the radar is used to track the target energy centroid, with in the radar tracking range, put a fake target around the target vessels (chaff bait), so that the radar can track the energy center of the real target and the fake target, and destroy the stable tracking of the target guided by the enemy guided radar. Finally, the radar is caused to turn from tracking the centroid to tracking the fake target under certain conditions. This type of interference is called centroid jamming.

The correct method of ship maneuver is an important condition for determining whether the centroid jamming is successful. After the launch of the jamming bomb, in the process of forming the centroid effect, the vessel should choose the appropriate heading and speed, and get rid of the enemy missile tracking as soon as possible. The ship maneuver is closely related to the direction and speed of the enemy missile attack, the wind direction of the current sea, and the launch direction of the own ship's jamming missile. If the own ship uses a combination of soft and hard weapons, then the ship maneuver should also consider whether it will affect the normal use of the sea-going missile or ship-borne gun weapon system. It can be seen that the ship maneuver by the chaff centroid is a complicated command decision problem. It is necessary to analyze the mathematical nature of ship maneuver by the principle of centroid jamming, establish the decision template of ship maneuver, and maneuverable decision-making method which can accurately quantify the calculation is given, which provides a reasonable basis for effectively exerting the efficiency of the centroid jamming and ensuring the overall coordinated combat capability of the ship.

2. Principle of Centroid Jamming

The object of centroid jamming is the enemy missile terminal guidance radar in the tracking segment. When a target(True or false) is simultaneously located in the tracking range of the tracking radar, the tracking radar's electric axis will point to the center of the radar cross-sectional area of these targets(Centroid, reflected energy center).According to this principle, the centroid jamming is used to interfere with the tracking segment of the missile's terminal guidance radar, so that the missile moves from tracking the state of the ship to tracking the energy center of the true and fake target(Centroid).Thereby achieving the role of protecting the ship. The schematic diagram of the principle of centroid jamming is shown in Figure 1.

  DOI: 10.25236/iciss.2019.071

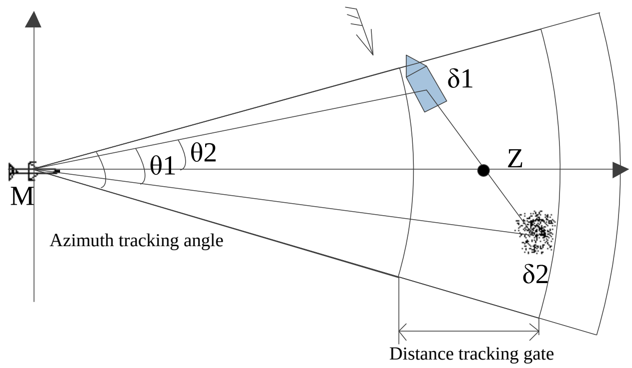

Fig 1. The schematic diagram of the principle of centroid jamming

In the figure, both the target ship and the fake target are in the missile's terminal guided radar tracking beam, the target radar cross-sectional area is δ_1,the fake target radar cross-sectional area is δ_2.Taking the M point of the current position of the missile as the reference, the true and fake target angle is θ_1,the angle between the centroid point Z formed by the missile terminal guidance radar tracking true and fake targets and the target ship is θ_2,then:

$$\theta_2 = \frac{\delta_2}{\delta_1 + \delta_2}\theta_1 \tag{1}$$

It can be seen from the above formula that the larger the cross-sectional area of chaff fale target radar, the larger the angle between the centroid and the target ship, the tracking point of the missile terminal guidance radar is farther away from the target ship.

By analyzing the principle of centroid jamming, it can be seen that successful centroid jamming requires the enemy missile tracking radar to complete two transfer processes: The first is to make the radar separately track the ship to the centroid point formed by the tracking ship and the fake target. The second is to make the radar track the centroid point to track the fake target separately. The ship must be tracked away from the radar to make the jamming successful.

The conditions required to complete the first transfer process:

The location of the fake target is within the tracking range of the terminal guidance radar; The radar cross-sectional area of the fake target is much larger than the radar cross-sectional area of the ship, which is generally greater than 2-3 times. The time from the launch to the formation of the jamming cloud is short, meanwhile, the time for airborne period is long; The incoming direction of the missile should be in a favorable angle with respect to the ship.

The conditions required to complete the second transfer process:

After the centroid effect is formed, the ship should choose the right direction maneuver, it need to get rid of enemy missile terminal guidance radar as soon as possible. At the same time, the launching of the interference shell should be beneficial to the ship from the missile tracking in the shortest time.

In summary, the launching of the interference shell and the direction of ship maneuver are important conditions for the success of the centroid jamming. The jamming cloud formed in the air after the launch of the interference shell is greatly affected by the constant wind in the sea surface. Ship maneuver is even more important at this time, reasonable ship maneuver (Course, speed) is the key to the success of centroid jamming.

3. Jamming Maneuver Calculation

First, we analyze the relative motion relationship between the centroid jamming of the true or false targets. As the figure shows, OT is the ship speed vector, OF is constant wind vector of the sea surface, OG is the combination of the two, which is named deck wind vector, OG is also the chaff fake target speed vector, OZ is centroid velocity vector, OM is incoming missile speed vector, the synthetic velocity vector of OM and OG is MG. The angular velocity of the fake target is ω_1,the angular velocity of centroid is ω_2.Among them:

$$OZ = \frac{\delta_2}{\delta_1 + \delta_2} OG \, , \omega 2 = \frac{\delta_2}{\delta_1 + \delta_2} \omega 1 \tag{2}$$

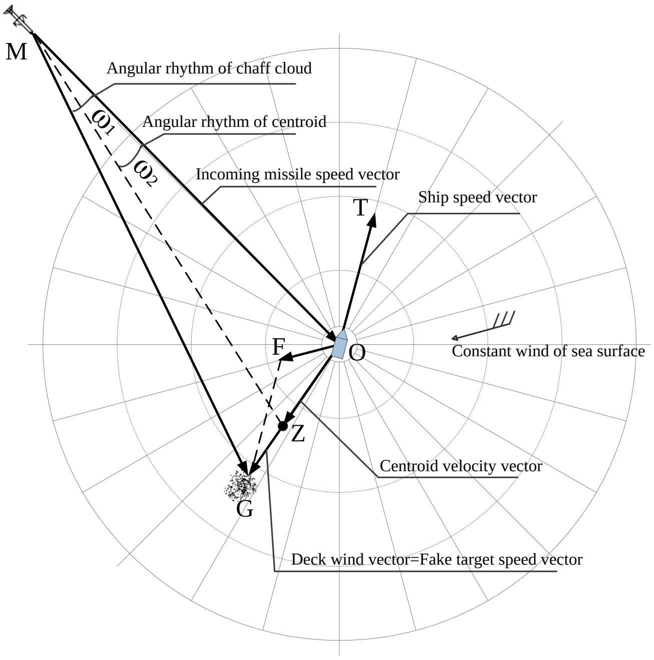

Fig 2. Schematic diagram of the relative motion relationship between the centroid jamming of the true or false targets

The process of centroid jamming is shown in Figure 3.After the target ship releases the fake target, due to the centroid effect, the missile terminal guidance radar is turned from the tracking target ship to the centroid point Z formed by the tracking ship and the fake target. At this time, missiles, ships and fake targets move simultaneously. If the ship moves in the right direction, the ship will leave the tracking gate of the terminal guidance radar before the fake target. The terminal guidance radar will only track the fake targets and the tracking will be successful.

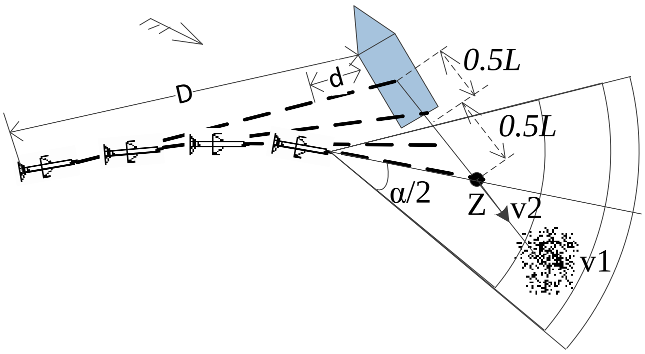

Fig 3. The process of centroid jamming

In the figure, v1 is the moving speed of the fake target, v2 is the moving speed of the centroid, vm is the speed of the missile attack, L is the physical length of the ship(Non-radar sectional area),D is the current distance of the missile, d is the minimum effective distance of centroid jamming,α is the angle of the azimuth tracking gate of the missile terminal guidance radar. The process of the above-mentioned centroid jamming can be concluded that the conditions for successful interference are as follows:

$$\omega 1 = f(v1)$$

$$t = (D - d) / v_m$$

$$v1 = [\delta_2 / (\delta_1 + \delta_2)] v2 \quad (3)$$
$$v2 \times t \geq L$$
$$(\omega 1 - \omega 2) \times t \leq \alpha / 2$$

In the above formula, *f* represents a function transition from a fake target velocity to an angular velocity and consists of a two-step trigonometric function. In ΔOFG of Figure 2, through the transformation trigonometric functions, the fake target velocity OG is obtained from the target ship velocity vector OT and the sea surface constant wind vector OF. In ΔOMG, through the transformation trigonometric functions, from the fake target velocity vector OG and the incoming missile velocity vector OM, the angular velocity ω1 of the fake target relative to the missile is obtained.

Then the value unit of ω1 is :

$$[\frac{LV_m \delta_2}{(D-d)(\delta_1 + \delta_2)}, \frac{\alpha V_m (\delta_1 + \delta_2)}{2\delta_1 (D-d)}] \quad (4)$$

Only by ensuring that ω1 is within this interval, can it be ensured that the fake target is always within the missile’s terminal guidance radar tracking. And when the missile reaches the minimum effective distance of the centroid jamming, it has deviated from the ship to a sage distance.

4. Simulation Analysis

A ship is heading direction of 350°and sailing speed of 18 knots, it is attacked by enemy anti-ship missiles suddenly, the anti-ship missiles’ azimuth is 50°and at a speed of 330 meters per second. The constant wind direction of the sea is 290° and the wind speed is 7meters per second. The ship will cooperate with the soft and hard weapons in accordance with the air defence plan. The ship-borne radar detected the terminal guidance radar signal at 25 km from the missile. The shipboard accusation system gives a centroid jamming decision based on the real-time situation; the commander fires the chaff projectile in time and cooperates with the ship maneuver.

Under the above situation, the course of the ship is in the range of 0-350° and the value of ω1 is as follows:

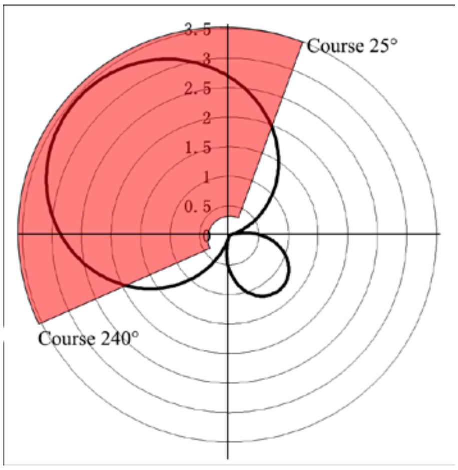

Fig 4. The relative angular velocity of a fake target in general sea state condition

We assume that the ratio of the cross-sectional area of the ship and the centroid target is 1:2,the actual physical length of the ship is 200 meters, the azimuth tracking angle of the incoming missile terminal guidance radar is 5°.The centroid jamming maneuver model given in Section 3 is available to ensure that the range of ω1 for successful centroid jamming is [2,3.7].The range of heading in this range of values is shown in the shaded area of Figure 4,the range of reasonable ship maneuver for centroid jamming is [240°,25°].

We assume that the sea surface constant wind speed is very large, reaching 20 meters per second.

At this time, the value of ω1 is as follows:

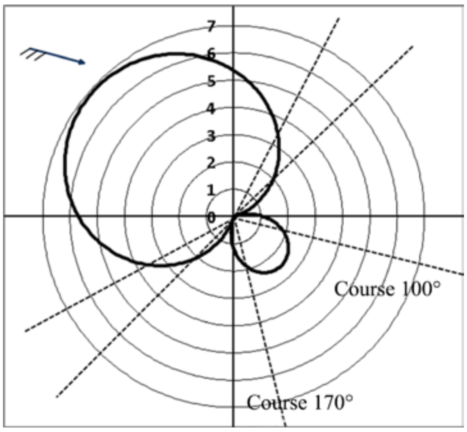

Fig 5. The relative angular velocity of a fake target in high sea state condition.

To ensure the centroid effect, the ship’s heading direction range is shown in the three intervals marked by the dotted line in Figure 5.Among them, the range of the heading direction is [100°,170°],and the direction of the incoming missiles is perpendicular to the situation. So in high sea state condition, if it is necessary to launch the centroid jamming, then follow the actual situation to take the approach of downwind maneuver to avoid.

5. Conclusion

Through the instance calculation of the ship maneuver with the centroid jamming in high sea state condition. It can be seen that the traditional experience of extensive command and decision-making methods cannot fully adapt to a variety of complex situations. The ship maneuver model with centroid jamming reveals the mathematical essence of centroid jamming and its avoidance maneuver. Transforming complex command decisions into quantitative calculation methods provides a scientific and reasonable basis for ensuring that commanders can make fast and accurate command decisions under various circumstances.

References

[1] Hubei Electromagnetic Compatibility Society. Principle and Application of Electromagnetic[M].Beijing: National Defense Industry Press,1996.

[2] Wang hongjun, Gao donghua. Electronic Warfare[M] .Dalian: Dalian Naval Academy,1996.

[3] Chen Qi, Ma Wei, Jiang Ning. Chaff Jamming and the Auxiliary Gun System Use Electromagnetic Compatibility Model[J].Firepower and Command Control,2007(10):112-115.

[4] MA Guo-zhong, WEI Gao, XU Jia-dong. Glint Analysis and RCS Computation for Radar Target[J]. Systems Engineering and Electronics, 1995 (2): 14~20.

[5] ZHAND De-bao, SHEN Peng. The Revision Method of Atmosphere Attenuation to Millimeter Wave RCS Measurement for Sea Target[J]. Mine Warfare & Ship Self-Defence, 2012 (2): 26~28.

[6] SONG Guang, LI Yong-xin, LIU Pan-long. Research on the Model of Millimeter-wave Attenuation in Atmosphere over Sea[J]. Mine Warfare & Ship Self-Defence, 2011 (2): 9~12.