2017 4th International Conference on Information Science and Control Engineering

Research on the Efficiency of the Chaff Jamming Corridor

Mingshan Lv
Department of Information Operation
Dalian Naval Academy
Dalian, China
2592779@qq.com

Longtao Wang
Department of Information Operation
Dalian Naval Academy
Dalian, China
13998430291@139.com

***Abstract*—In the face of multiple radars and chaff motion, the blanket capability of the chaff jamming corridor is uneven. The basic tactical requirements are analyzed, and the efficiency analysis model of the chaff corridor is put forward based on the chaff characteristics and the actual combat scenario. Some recommendations for the combat application of the chaff jamming corridor are proposed by simulation.**

Chaff corridor; motion model; combat efficiency

I. INTRODUCTION

To prevent the opposite radars from getting the information of the attack planes, the chaff jamming corridor is always adopted by the air force in anti-ship or anti-land warfare. Traditionally the screen function of the chaff corridor is considered to be effective when the chaff RCS in the radar distinguishing cell is bigger than the attack plane's RCS. With the application of the coherent technique such as MTI in radar, the attenuation capability becomes another important factor considered in its application, and always depends on the density and the length that the radar wave penetrates the chaff corridor.

Presently many papers have discussed the problem about the chaff jamming corridor. In [1], the tactical application of the chaff corridor is discussed. Reference [2] and [3] analyzes the chaff motion model based on the chaff characteristics. Reference [4] and [5] present the model of the jamming efficiency to the MTI Radar and the ground early warning radar respectively. Reference [6] proposes the methods to upgrade the blanket effect for the unequal density chaff corridor. The common weakness in above references is that they didn't combine two factors in simulating the efficiency of the chaff corridor. One is that the chaff corridor is always faced with multiple radars located in different positions and with different capabilities. Another is the chaff motion that will result in the uneven blanket capability at different moment.

In the case of the multiple radars and chaff motion, the chaff casting interval and casting amount is concentrated on in this paper that will be organized as follows: Section 2 discusses the basic tactical requirements for the chaff jamming corridor. In Section 3 the chaff casting intervals are analyzed when the chaff corridor faces multiple radars located in different positions. Section 4 researches on the efficiency analysis model of the chaff corridor based on the chaff characteristics and the actual combat scenario. A simulation example is given in section 5. Finally, Section 6 concludes this paper with future work.

II. BASIC TACTICAL REQUIREMENTS FOR THE CHAFF CORRIDOR

The single chaff jamming corridor and the inter-cross chaff jamming corridor are the two basic tactics adopted by the aircraft when they attack the surface and land targets [1]. Taking the single chaff jamming corridor shown in Fig. 1 as an example, to blanket the information of the attack planes, its start point *A* and end point *B* are up to the positions and capabilities of the radar R_1 and R_2, and the attack range of the weapon shipped on the attack plane is also taken into consideration.

The requirements of the width and height of the chaff corridor discussed in [2] will not be involved in this paper. Obviously, when the length, the width and the height is satisfied with the combat requirements, the combat efficiency of the chaff corridor will rely on the chaff casting interval and amount.

III. CHAFF CASTING INTERVALS

The assumption that the chaff is cast with the equal speed and equal amount is always taken in simulation by many papers such as [4] and [5], which will result in the waste or lack of the chaff. The appropriate policy is that the chaff package is cast one by one in the radar distinguishing cell along the attack route.

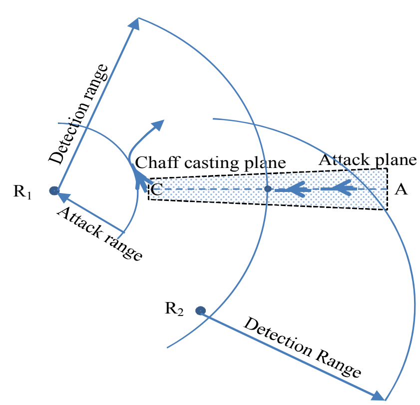

Figure 1. Single chaff jamming corridor.

978-1-5386-3013-6/17 $31.00 © 2017 IEEE
DOI 10.1109/ICISCE.2017.349

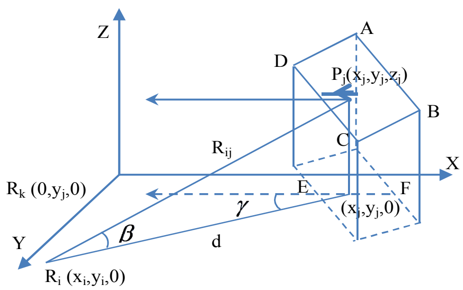

Figure 2. Chaff casting intervals.

It is obviously that the chaff corridor always faces the multiple radars located in different positions and the attack plane is in the motion, so the radar distinguishing cell is variable along the attack route. To analyze the interval requirement of the chaff cast to the radar R_i, the coordinate system is created as the Fig. 2. The attack course is P_j to R_k. The square *ABCD* means the distinguishing cell of the radar R_i. *EF* is the chaff casting interval.

The pitching angle β of the radar R_i can be formulated as:

$$\beta = \arctan(|z_i|/d) = \arctan(|z_i|/(x_j-x_i)^2+(y_j-y_i)^2)^{1/2}). \quad (1)$$

The angle γ of the attack route relative to the connection between the radar R_i and the attack plane P_j can be formulated as:

$$\gamma = \arctan(|y_i-y_i|/|x_j-x_i|). \quad (2)$$

The range R_{ij} between the radar R_i and the attack plane P_j can be formulated as:

$$R_{ij} = ((x_j-x_i)^2+(y_j-y_i)^2+(z_j-0)^2)^{1/2}. \quad (3)$$

Use (1), (2) and (3), the chaff casting interval D_i can be formulated as follows:

$$D_i = \mathrm{EF} = \tau_i \cdot c/2 \cdot \cos\beta/\cos\gamma, \quad \gamma>=0 \text{ and } \gamma<\theta \quad (4)$$

$$D_i = \mathrm{EF} = 2 \cdot \tan(\phi_i/2) \cdot R_{ij}/\sin\gamma, \quad \gamma>=\theta \text{ and } \gamma<90. \quad (5)$$

Where $\theta=\arctan(4\cdot\tan(\phi_i/2)\cdot R_{ij}/(\tau_i\cdot c))$, c is the velocity of the light, τ_i is the pulse width of the radar R_i, ϕ_i is the level beam width of the radar R_i.

When the chaff corridor faces n radars, the casting intervals of the casting plane can be denoted as:

$$D = \min(D_i), \quad i=1,2,\cdots,n. \quad (6)$$

IV. The Efficiency Analysis Model of the Chaff Corridor

A. The Blanket Coefficient

After the chaff corridor is disposed, two kinds of signals will be received by the radars. One is the target echo after dispersion by the chaff, another is the chaff echo. If we define the blanket coefficient K_{CT} as S_C/S_T, then the K_{CT} can be represented as [6]:

$$K_{CT} = \sigma_C/\sigma_T \cdot e^{2\cdot nc\cdot 0.17\cdot\lambda\cdot\lambda\cdot hc}. \quad (7)$$

Where σ_C and σ_T is the RCS of the chaff and the target respectively, *hc* is the thickness of the radar wave penetrating the chaff corridor, *nc* is the density of the chaff corridor, λ is the radar wave length. The σ_T is relative to the target's characteristics and the σ_C is relative to the chaff amount in the radar distinguishing cell, which is not discussed here.

B. The Chaff Motion Model

After the chaff casting intervals are confirmed, the chaff amount and the motion model will decide the density and thickness of the chaff cloud which will affect the combat effect greatly.

According to the chaff characteristics and the actual combat scenario, some assumptions can be taken as follows:

- Chaff corridor length is *L*, the velocity of chaff casting plane is V_p, and the chaff is cast from the moment t_s.
- The route of the chaff casting plane is straight, and the chaff amount is N_i in the height of H_i at the moment t_i with the interval D_i.
- The attack plane lags the chaff casting plane ΔT second, and fly along the chaff corridor with the velocity V_g.
- After the chaff is cast, the chaff cloud is formed to be ellipsoid with the length d_i, the width w_i and the depth h_i. The actual size is decided on the design and the type of the chaff casting device and the casting position etc.
- The falling velocity of the ellipsoid chaff cloud is V_0, which is decided on the height, the air density and air pressure where the chaff is cast.
- The motion velocity on the width is V_w.
- The motion velocity on the height is V_h, which is decided on the difference of the top chaff falling velocity V_u and the substrate chaff falling velocity V_d.

C. The Chaff Density When the Attack Plane Flies at the Moment T

In terms of the above assumptions, the following results can be got:

1) When the attack plane flies at the moment T, the moment t_i the chaff cast by the chaff casting plane can be formulated as:

$$t_i \cong V_g\cdot(T - t_s - \Delta T)/V_p + t_s. \quad (8)$$

2) The volume V_T of the chaff cloud at the moment T can be formulated as:

$$V_T = \pi \cdot w_T/2 \cdot h_T/2 \cdot d_T. \quad (9)$$

Where w_T, h_T and d_T present the width, the depth and the length of the chaff cloud at the moment T, and can be described as follows:

$$w_T = w_i + V_w \cdot (T - t_i + \Delta T). \quad (10)$$

$$h_T = h_i + V_h \cdot (T - t_i + \Delta T). \quad (11)$$

$$d_T = V_p \cdot (t_{i+1} - t_i + \Delta T). \quad (12)$$

3) The density ni of the chaff cloud at the moment T can be described as:

$$n_i = N_i/(\pi \cdot w_T \cdot h_T \cdot d_T/4)\ . \quad (13)$$

D. The Thickness of the Radar Wave Penetrating the Chaff Cloud When the Attack Plane Flies at the Moment T

As shown in Fig. 3, the radar wave penetrates the radar cloud from the B to A, so the AB is the thickness of the radar wave penetrating the chaff cloud. Although the whole chaff corridor is uneven in size, but in the curtain span of the chaff corridor, we can assume its size is even which is convenient for analysis.

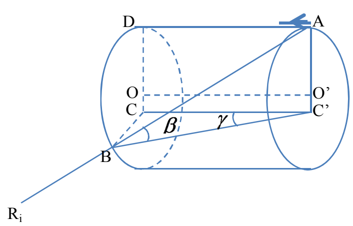

Figure 3. The Thickness of the Radar Wave Penetrating the Chaff Cloud.

According to the ellipse characteristics and geometry relations, the following equations can be got:

$$OC^2/(h_T/2)^2 + BC^2/(w_T/2)^2 = 1. \quad (14)$$

$$OC = O'C' = AB \cdot \sin\beta - h_T/2. \quad (15)$$

$$BC = AB \cdot \cos\beta\sin\gamma. \quad (16)$$

Based on (14), (15) and (16), the thickness hc of the radar wave penetrating the chaff corridor can be denoted as:

$$hc \cong h_T \cdot (w_T/2)^2 \cdot \sin\beta/[(w_T/2\sin\beta)^2 + (h_T/2\cos\beta \cdot \sin\gamma)^2]. \quad (17)$$

V. SIMULATION

A. Input Scenario

The basic scenario is the same as the Fig.1 shows. The single jamming corridor is adopted, and there are two radars on the attack route and their wave length is 0.1 meter. Other parameters of the two radars are shown in the following table. The attack range of the weapon on the attack plane is 80000 meters.

According to the chaff characteristics and the actual combat scenario, other parameters can be assumed as follows:

- The velocity V_p of the chaff casting plane is 200 m/s.
- The chaff amount N_i is 500000 pieces per times.
- The height H_i of the chaff cast is 12000 meters.
- The attack plane lags the chaff casting plane 300 seconds.
- The initial width w_i of the chaff cloud is 15 meters and the initial depth h_i is 3 meters.
- The falling velocity V_0 of the chaff cloud is 0.5 m/s.
- The motion velocity V_w of the chaff cloud on the width is 1.0 m/s.
- The motion velocity V_h of the chaff cloud on the height is 0.5 m/s.
- The falling velocity V_u of the top chaff is 0.8 m/s and the falling velocity V_d of the substrate chaff is 0.2 m/s.

B. Output

The simulation results in matlab 6.5 are shown in Fig. 4, Fig. 5 and Fig. 6. Fig. 4 shows the chaff casting interval as the casting plane is closing to the radar R_1. Fig. 5 shows the thickness hc of the radar R_2 wave penetrating the chaff corridor as the attack plane is closing to the radar R_1 at different V_g. Fig. 6 shows the blanket coefficient K_{CT} to the radar R_2 as the attack plane is closing to the radar R_1 at different V_g.

C. Some Recommendations

1) The efficiency of the chaff corridor is complicated. So all factors such as the combat scenario, the locations and the capabilities of the radars, the chaff motion should be taken into consideration when the efficiency of the chaff corridor is researched on.

TABLE I. RADAR PARAMETERS

Radar	**Parameters**			
	Coordinate /km	***Max detecting range /km***	***Distinguishing angle of azimuth /degree***	***Pulse width /µs***
R1	(0,0,0)	250	3	10
R2	(80,70,0)	400	4	10

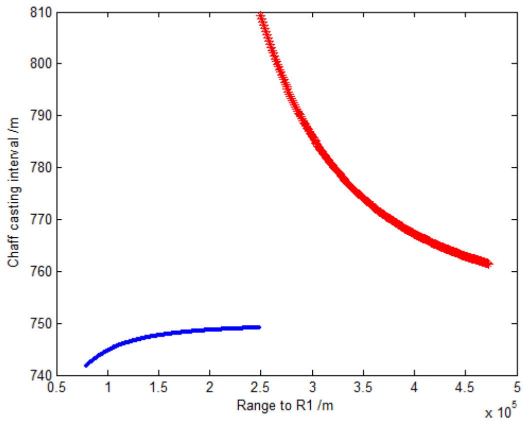

Figure 4. The Chaff Casting Intervals in Different Range.

2) The thickness and the blanket coefficient is variable when the velocity of the attack plane is not equal to the velocity of the chaff casting plane. So the operation of the airplanes should not be omitted on the efficiency evaluation of the chaff corridor.

3) The width of the chaff corridor should be pay more attentions, because the thickness is sensitive to the location of the radar. That is， the range is closer to the attack target and the the thickness is smaller.

4) With the application of the coherent technique such as MTI in radar, it is reasonable that the blanket coefficient is used to evaluate the the combat efficiency of the chaff corridor.

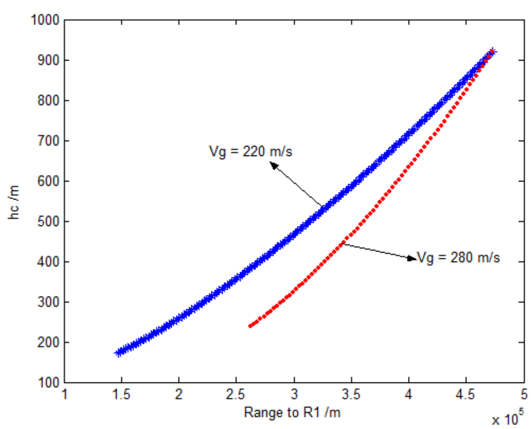

Figure 5. The Thickness in Different Range.

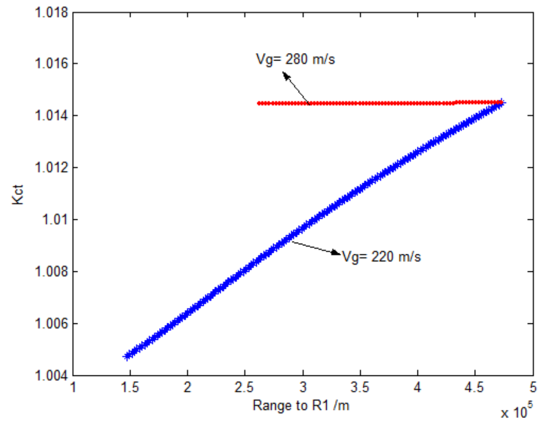

Figure 6. The Blanket Coefficient in Different Range.

VI. CONCLUSION

In the face of multiple radars and chaff motion, the blanket capability of the chaff jamming corridor is uneven. That is, the combat efficiency of the chaff corridor should be evaluated dynamically. So the chaff is cast with the equal speed and equal amount is unreasonable and more attentions should be paid to the chaff casting intervals and amount.

In this paper some reasonable recommendations are proposed by simulation and analysis, but some factors are not taken into consideration yet such as the chaff RCS. The chaff RCS is up to the chaff amount in the radar distinguishing cell and the chaff amount is affected by the volume of the chaff cloud and the size of the radar distinguishing cell. To simulate more precisely, analysis on the chaff RCS is our further work.

VII. REFERENCES

[1] CAI Gan, ZHANG Ke, LI Yan-jun, “Tactical Application Research of Chaff Corridor,” Fire Control and Command Control, Vol. 33, No. 7, July. 2008, pp. 44-47.

[2] CAI Wan-yong, LI Xia, WAN Shan-hu, WANG Zhong-jie, “Model of Chaff Motion Trajectory and Curtain Wall Diffusion in Air Environment,” Systems Engineering and Electronics, Vol. 31, No. 31, Mar. 2009, pp. 565-569.

[3] WANG Hong-xun, WANG Xing, WANG Hong-wei, “Analysis on Mechanism and Efficiency of Surface Air Complex Chaff Corridor,” Modern Defence Technology, Vol. 40, No. 5, Oct. 2012, pp. 145-149.

[4] LU Jing-shuang, HU Song, ZHOU Rui, “Research into The Jamming Efficiency of Corridor Chaff to MTI Radar,” Shipboard Electronic Countermeasure, Vol. 32, No. 4, Aug. 2009, pp.31-33.

[5] Su Fu, Wang Xiao-nian, Pi Jun-ming, Zhang Ru-tong, “Simulation and Analysis of Jamming Effectiveness of Jamming Corridor on Ground Early Warning Radar,” Fire Control Radar Technique, Vol. 36, Sep. 2007, pp. 57-60.

[6] WANG Hong-xun, YE Guang-qiang, WANG Hong-wei, QIAO Qing-gang, “Unequal Density Chaff Corridor and its Blanket Effect Upgrade,” Telecommunication Engineering, Vol. 51, No. 4, Apr. 2011, pp. 35-38.