Beam Cutting Effect on Jamming Efficiency of Chaff Corridor

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Abstract: Cutting effect was unconsidered so far for Chaff Corridor (CC) both in theoretic analysis and operational engineering; different position's Blanket Efficiency (BE) of constant chaff-density CC is different as results of radar-lobes cut a chaff volume, which means there are limited chaffs which have jamming effect to radar. So CC's Jamming BE was researched and modified, even and un-even CC's chaff density of jamming efficiency were turned out by simulation, the results showed that if CC's BE was wanted unaltered, the chaff density should be changed correspondingly.

Ⅰ Introduction

Chaff Corridor(CC) blanketing effects has been depressed or impaired with developments of radar technology, it holds good as one of important blanket jamming methods so far when air attacks assault designated radars, as CC is easy to extend and to use, low cost, and have universal blanket jamming effects to lots and kinds of radars. Most technologies which confront CC are owing to Doppler effects of chaffs and real targets for radar, so methods and means were tried and considered to re-secure CC's Blanket Efficiency (BE), Such as CC jamming principles in [1][2], chaff mechanical moving characters in atmospheres in [3], basic jamming theory and laying modes in [4], tactical application and its impression in distinct occasions, measure for measure in [5]-[8], intrinsic attenuation characteristics for kinds of radar waves in [9]-[15]. But all of above References were keep same implicit foothold, a precondition that radar's beam was un-considered. But in fact radar's beam is a real material and has its own shape, which means number of chaffs that scatter electromagnetic signals was limited and restricted, so the CC's blanketing theory should be re-analyzed and modified.

Ⅱ Traditional Chaff Corridor

A CC using scenario is given in Fig.1, to cover the plane T, chaffs with given frequency-characters were scattered abundantly to form **CC** in atmospheres, which can blanket T from Radar R. And the path of electromagnetic waves of radar was not vertical, but acclivitous relative to the jamming CC. The echo received by radar can be sorted into two kinds in Fig.1, one echo was direct rebound from T, which was expressed as P_{RTR}, the nother was direct rebound from chaff, which was expressed as P_{RCR}. Blanket Coefficient(BC) is defined to scale CC's BE as $k_{CT}= P_{RCR}/P_{RTR}$, According to [1] and [2], P_{RTR}, P_{RCR} and k_{CT} can be expressed as Eq. 1, Eq. 2 and Eq. 3. Comparative BC (CBC) was adopted in [16] where pointed the effects of radio skew transmission should be considered in. there was a common Equation as Eq. 4, at beginning was Eq. 5, CBC is defined as Eq. 6. According to Fig.1, and a define was given as Eq. 7 and Eq. 8, at least CBC was expressed as Eq. 9.
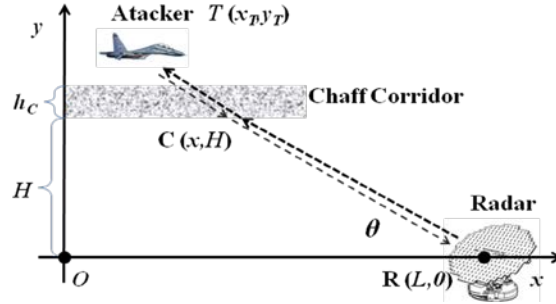
Figure 1 Common CC Jamming Sketch

$$P_{RTR} = \exp[-0.34 n \lambda^2 h_c] P_R G_R^2 \sigma_T \lambda^2 / [(4\pi)^3 R_{RT}^4] \tag{1}$$

$$P_{RCR} = P_R G_R^2 \sigma_C \lambda^2 / [(4\pi)^3 R_{RC}^4] \tag{2}$$

$$k_{CT} = \exp(0.34 n \lambda^2 h_c) \sigma_C / \sigma_T , \quad R_{RT} \approx R_{RC} \tag{3}$$

$$k_{CT} = \frac{0.17(2H + h_c) h_c \theta_{0.5H} \theta_{0.5V} R_{RC}^2 n \lambda^2}{2\sigma_T H^2} e^{0.34 \frac{n \lambda^2 h_c}{\sin\theta}} \tag{4}$$

$$k_{CT0} = \frac{0.17(2H + h_c) h_c \theta_{0.5H} \theta_{0.5V} R_{RC0}^2 n_0 \lambda^2}{2\sigma_{T0} H^2} e^{0.34 \frac{n_0 \lambda^2 h_c}{\sin\theta_0}} \tag{5}$$

$$k = k_{CT} / k_{CT0} , \quad \sigma_T \approx \sigma_{T0} \tag{6}$$

$$k_1 = R_{RC}^2 / R_{RC0}^2 \tag{7}$$

$$k_2 = \exp[0.34(n R_{RC} - n_0 R_{RC0}) \lambda^2 h_c / H] \tag{8}$$

$$k = k_1 k_2 \tag{9}$$

Where from Eq. 1 to Eq. 7 P_R is radar radiant power, G_R is the gain of the radar's antennas, σ_T is target's equivalent Radar-Cross-Section (**RCS**), λ is radar RF wavelength. R_{RT} is range between radar and target, R_{RC} is range between radar and chaffs, σ_C is chaffs' **RCS** in one radar resolution cell, n is CC's chaff density, h_C is CC's thickness, and H, highness, θ is the main lobe beam's vertical angle, beam horizontal half width was $\theta_{0.5H}$, beam vertical half width was $\theta_{0.5V}$, R_{RC0} is range between radar and CC's beginning. Also L is defined as radar's location, which will be used later.

Ⅲ Beam Cutting Effect

A. Beam Cutting of Main Lobe

Radar main beam was often considered in use, which was unconsidered before from [1] to [15]. In fact in Fig. 2, it had great effect to CC and should be considered as it meaned that there were only part of CC has jamming effect and effective, so chaffs' number was limited in CC.n in Eq. 6 means chaff number which scattered electromagnetic power and in the cross part of radars beam. There was n/n_0 in Eq. 7 which was missed. According to Eq. 7 and Fig. 2, an obviously corrective conclusion about n or n_0 should be inferred as Eq. 10.
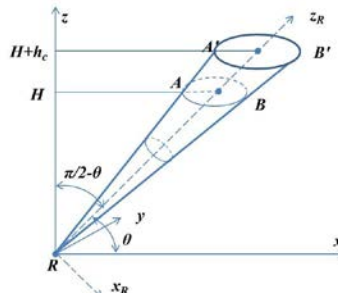

Figure 2 Main Lobe Beam Cutting Sketch

$$n = n_c V_c \tag{10}$$

Where n_c means real density of CC, and V_c stands for volume of beam cutting shape. Eq. 10 means n/n_0 was related with two factors, one was the radar beam cutting space in CC, the other was chaff thickness. So Eq. 9 should be modified as Eq. 11.

$$k = k_0 k_1 k_2 k_3 \tag{11}$$

$$k_0 = n_c / n_{c0} \tag{12}$$

$$k_3 = V_c / V_{c0} \tag{13}$$

B. Volume of Beam Cutting

According to the stereoscopic relationship in Fig.2, After a series of Mathematical derivation combined with Fig.1, the volume of beam cutting should be expressed as Eq. 14. Also there was a relation as Eq. 15 in Fig.1, there was a relationship, k_3 could be introduced out as Eq. 16. Also k_2 could be modified as Eq. 17. Equation 17 means that if k_0 was changed, k_2 would be changed too, also according to the stereoscopic relationship, Eq. 11 should be modified as Eq. 18.

$$V_C = \frac{(H^2 h_C + H h_C^2 + h_C^3/3)\pi tg\theta_{0.5V} tg\theta_{0.5H}}{(\sin^2\theta - \cos^2\theta \cdot tg^2\theta_{0.5V})^{1.5}} \tag{14}$$

$$\begin{cases} \sin^2\theta = H^2/[H^2 + (L-x)^2] \\ \cos^2\theta = (L-x)^2/[H^2 + (L-x)^2] \end{cases} \tag{15}$$

$$k_3 = \frac{V_C}{V_{C0}} = \frac{[H^2 + (L-x)^2]^{1.5}[H^2 - L^2 tg^2\theta_{0.5V}]^{1.5}}{[H^2 + L^2]^{1.5}[H^2 - (L-x)^2 tg^2\theta_{0.5V}]^{1.5}} \tag{16}$$

$$k_2 = \exp[0.34(k_0 R_{RC} - R_{RC0})n_0 \lambda^2 h_c / H] \tag{17}$$

$$k = k_0 k_1 k_2(k_0) k_3 \tag{18}$$

C. Reference of C

According to [2], if radio waves power is attenuated to a degree of $\Delta p(dB)$ for CC, there was a ralation as Eq. 19, the original chaff density of CC could be introduced as Eq. 20. As mentioned above, radio waves power is sanded and intercepted by radar in a skew path relative to CC, so Eq. 20 should be modified as Eq. 21.

$$\Delta p = 2\beta h_C, \beta = 0.738 n_0 \lambda^2 \tag{19}$$

$$n_0 = \Delta p/[1.476 h_C \lambda^2] \tag{20}$$

$$n_0 = \Delta p \sin\theta/[1.476 h_C \lambda^2] \tag{21}$$

Combined with Eq. 5, the reference BC. of the corridor beginning could be drowed out.

IV Comparative Simulation

Assuming a CC was scattered to jam to the radar, where L=100 km, H=6km, h_c=0.5km, λ=5cm,the RCS of taget was 15m^2, for a given attenuation degree of $\Delta p=60dB$, according to Eq. 24 and Eq. 3, the initial chaff density and the wanted BC of CC could be got as Eq. 22.

$$n_0 = 33, \; k_{CT} = 0.0009 \tag{22}$$

In such case, in fact the real BC was Eq. 23 according to Eq. 5, and the initial chaff density according to Eq. 21, the CC's BC according to Eq. 5.

$$k_{CT} = 25.76, n_0 = 3, k_{CT0} = 1.893 \tag{23}$$

Modified initial chaff density was less than the traditional's, which mean that mass chaffs could be saved.

A. Simulation of Even CC

By all appearances, if the CC has a even chaff density from cover to cover, the closer from CC's position to radar, the smaller CBC k will be. For the given scenario of Fig.1, k were showed in Fig.3, especially, when the position is about 20Km away to radar, k will be about **-40dB**, a rather small value.
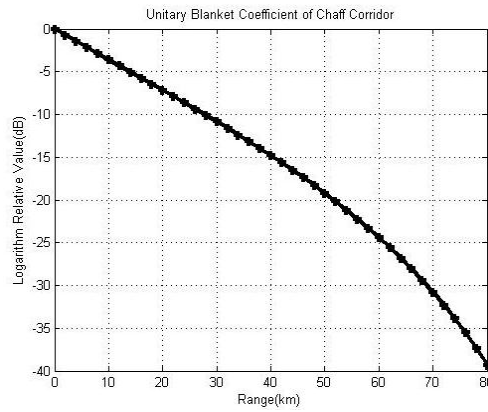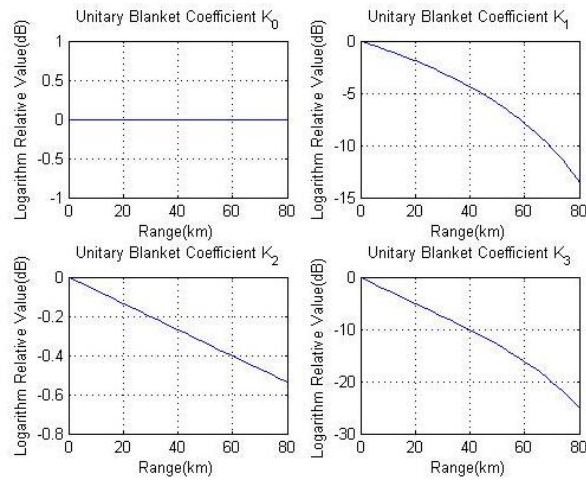
Figure 3 CBC Logarithm Curve

Figure 4 parameters of k in logarithm

Sub-parameters were showed in Fig.4 according to Eq. 12, Eq. 7, Eq. 17 and Eq. 16. Though k_0 was unchanged, others were attenuated, especially k_1 and k_3 were decayed greatly.In such status, if such an even CC is laid, the needed chaff number should be figured out firstly. If it was figured out according to CC's end position nearest radar, mass of chaffs will be waste; otherwise if it was figured out according to CC's begin position far from radar, CC's BC for radar will not be assured.

B. Simulation of Un-even CC

If CC was expected to jam effective from over to over, k should be nearly invariable, which means that CC's thickness or chaff density should be altered. As aeroplanes which scatter chaffs to form jamming CC usually fly at a constant velocity, chaff thickness is hard to customized relatively, but chaff density is reversely easy. The latter way was selected to change k, in another word, the sub-parameter k_0 should be changed. But according to Eq. 17, if k_0 was changed, k_2 was changed spontaneously too. So a testing by testing way was adopted to make the k keep common and even by Eq. 21. The results of sub-parameters was showed in Fig. 5.
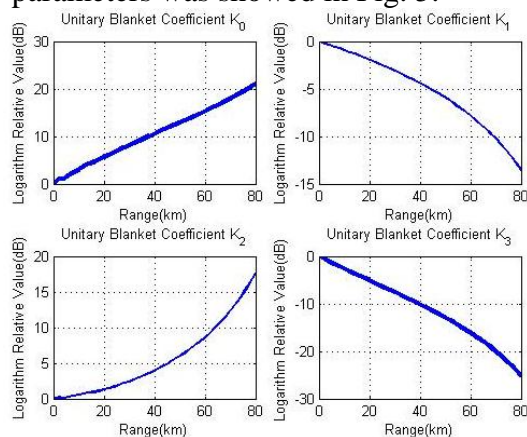

Figure 5 improved Parameters of k in logarithm

k is showed in Fig.6, which keeping constant in the rough. In Fig.5, the k_0 was almost an oblique line in logarithm, which signified that the chaff density should be promoted in an exponent level.
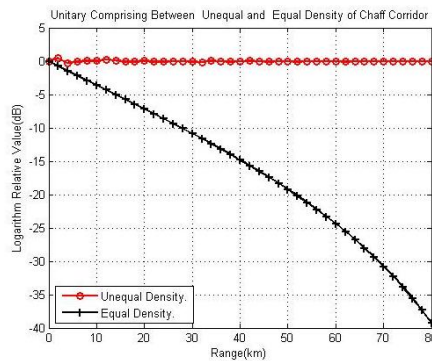

Figure 6 Upgrade CBC Curve

Ⅴ Conclusion

It must be pointed out that there are many factors that are correlative with CC's BC, and should be considered synthetically in practice. But in any case, the chaff density is also one of importants for CC's BC, which was not concerned before. CC has distributed BC. Similar analysis can be carry out in the before-mentioned way in situation such as laying side CC to radar, or jamming two or more radars, and results will be likeness. This is important to upgrade CC's BC, and will promote CC's performance in practice.

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