# Research on meliorative average RCS of single chaff

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*Abstract*—**Aiming at the calculation problem of chaff preparing of mix-packed in a chaff bag, the new method of chaff preparing is bright forward. According to the chaff characteristic of frequency response, the model of single chaff RCS is established. The method can effectively achieve Chaff suppressive Jamming on all frequency, when considering radar countermeasure Intelligence.**

***Keywords-chaff; radar countermeasure intelligence; suppressive jamming***

## I. INTRODUCTION

In modern air defense radar system, alert, fire control and other radar in the L, S, C, X, Ku, K, Ka bands of different work, the use of chaff corridors to ensure the chaff to jam enemy radar interference bandwidth to the corridor covering multi-band, so as to have good interference effects, to successfully cover penetration strike aircraft.

Our existing chaff filaments from several centimeters to twenty centimeters and so the length of the existing models in the calculation of the required number of chaff wire is used to meet the delivery capacity of the pod itself is put in the method of calculating the radar against the use of intelligence is insufficient, needed only to calculate the different segments of different bands put the number of chaff packets, this will not only result in the number of chaff silk waste, lower cost-effective, and may not reach enough to interfere with the bandwidth in certain routes was found to penetrate enemy radar aircraft. Complex electromagnetic environment in a modern electronic warfare, enemy air defense system by radar network covers the entire spectrum of the main form does not guarantee that all band radar chaff corridor interference.

Therefore, we should make full use of radar interference against the band of intelligence information provided presents a general method of chaff ratio of silk to meet the complex electromagnetic environment, the cover of Chaff corridor penetration strike aircraft requirement.

## II. CHAFF CLOUD MODEL

Chaff electromagnetic radiation at different frequencies will produce a different effective scattering area. In general, the effective half-wavelength resonant scattering largest chaff, chaff reflects the frequency response characteristics of the use of electromagnetic properties.

Seen by the radar principle, the radar echo power and the objectives of the reflection area is proportional to the radar echo power that contains the target's RCS information, if obtained chaff cloud echo power spectrum, we can get the chaff in the broadband segment radar cross section curve.

## III. ECHO POWER MODEL OF CHAFF CLOUD

Assuming chaff cloud to meet the following conditions:

(1) the full spread of chaff in the air, a slow descent, and at some point into the radar antenna beam of the number of chaff and chaff out of the radar antenna beam is approximately equal to the number;

(2) in the interval of two-wavelength dipole chaff above, can ignore the interaction between the chaff dipole coupling effect;

(3) scattering amplitude and phase of unrelated, random chaff dipole orientation.

On the basis of the above conditions, the signal can be as smooth chaff cloud scattering signal, and is the echo of each chaff dipole vector. Synthetic echo signal:

$$S = U\exp(j\theta) = \sum_{k=1}^{N} A_k \exp(j\phi_k) \tag{1}$$

Here, U is the synthetic interfering signal amplitude, $\theta$ is the signal phase for the synthesis of interference, the k-th echo signal amplitude chaff, chaff for the k-th echo signal phase. When N large enough chaff cloud echo signal can be drawn for the Rayleigh distribution of amplitude, phase evenly distributed.

Under normal circumstances, the chaff cloud and radiation spectrum of the reflected signal of the chaff cloud signal spectrum is not the same, this difference is due to the chaff cloud by the wind, gravity, air and other effects lead to the average Doppler frequency shift.

Assuming the dipole chaff cloud may be to exercise, the chaff echo power spectrum model:

$$G(f) = (a\lambda_0 / 4\pi)\exp(-(a\lambda_0 f / 4\sqrt{2}\pi)^2) \quad (2)$$

Here, $\lambda_0$ is chaff dipole resonance wavelength, a is the quality of chaff dipoles, Boltzmann constant and absolute temperature constant. From (2) can be seen, chaff echo power of the power spectrum has a Gaussian form.

Chaff cloud $f_0$ center frequency of the power spectrum:

$$G(f) = (a\lambda_0 / 4\pi)\exp(-(a\lambda_0 (f - f_0) / 4\sqrt{2}\pi)^2) \quad (3)$$

Namely:

$$G(f) = (a\lambda_0 / 4\pi)\exp(-(a\lambda_0 (f - c/\lambda_0) / 4\sqrt{2}\pi)^2) \quad (4)$$

## IV. Frequency Response Model of Chaff Cloud

Seen by the radar principle, the radar receives the target echo power and the target is proportional to the effective reflection area, namely:

$$\sigma = \frac{(4\pi)^3 R^4 P_r L}{P_t G_t^2 \lambda_0^2} \quad (5)$$

Here, $P_t$ is peak value power of radar transmitter, $G_t$ is plus of radar transmitter antenna, $\lambda_0$ is syntony wavelength of chaff dipole, $\sigma$ is efficiency echo area of object, $R$ is distance of object and radar receiver, $L$ is system wastage of radar.

Taking into account the radar receiver sensitivity reflects the radar's ability to minimum detectable signal, the signal can be considered as a chaff cloud radar target object, the type (4) into (5) to get a single effective dipole chaff reflection area:

$$\sigma = \frac{(4\pi)^3 R^4 L}{P_t G_t^2 \lambda_0^2}(a\lambda_0 / 4\pi)\exp(-(a\lambda_0 (f - c/\lambda_0) / 4\sqrt{2}\pi)^2) \quad (6)$$

It can be simplified as:

$$\sigma = 0.213\lambda_0^2 \exp(-(a\lambda_0 (f - c/\lambda_0) / 4\sqrt{2}\pi)^2) \quad (7)$$

Chaff bandwidth defines the maximum average effective reflection area for half of the reduced frequency range. It can be seen from Figure 1, in order to get a larger effective reflection area, basically using a half wavelength dipole resonant chaff. But the chaff of the half-wavelength resonance peak is very sharp, its bandwidth is typically only the center frequency (or wavelength) of (15 ~ 20%), apply a very narrow band.

Increase the bandwidth of chaff packet interference in two ways: First, increase the diameter of chaff, so their bandwidth increased chaff; two different lengths of chaff is used to increase the chaff mixed packaging bandwidth.

Increase the chaff diameter (or width), bandwidth, despite the increase, but this will increase the chaff of the weight and volume, resulting in increased rate of decline of chaff, empty interference time, unit weight and unit volume reduce the effective reflection area of chaff and a series of ills. Therefore, a small diameter should be used chaff, and use a variety of different lengths of chaff to get broadband. With fine chaff, the chaff number per unit volume can be increased; will help get a large effective reflection area.

Figure 2 is the length of chaff from the five different packaging form of mixed filament cross section of the frequency response curve. Among them, the length of the wire 200 chaff, chaff length of wire 1000, wire 6000 chaff length, length of the wire 15000 chaff, chaff length of wire 50000.

It can be seen, the interference from 0.5GHz to cover the bandwidth of 8GHz frequency band, interference with a larger bandwidth.

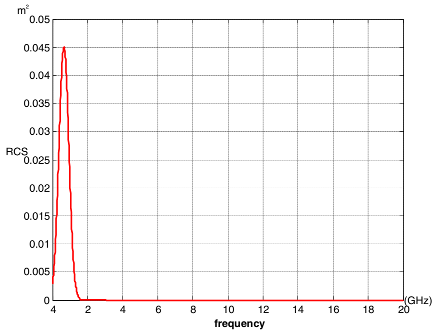



Figure 1. Dispersion section and frequency response of singularity length chaff.

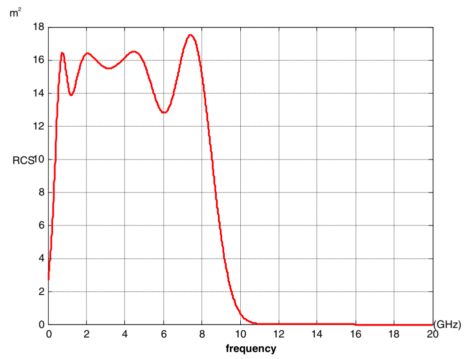



Figure 2. Dispersion section and frequency response of chaff mixed bag

## V. Algorithm for the Proportion of Chaff Wires

In order to achieve sufficient interference chaff bandwidth wire chaff mixed bag with the loaded bag filled way. Of chaff packets interference bandwidth and the ratio of the proportion of chaff wires, length and other parameters relevant, wire chaff ratio determines the effect.

Broadening the bandwidth effect of chaff algorithm is shown in Figure 3. Bandwidth is defined under the chaff, to ensure maximum effective scattering cross section of chaff to be a cover for the effective reflecting surface attack aircraft twice under the conditions of the formation of a variety of different length wire chaff mixed bag to completely cover the bandwidth from the between the band and the increased bandwidth of a single species of chaff.

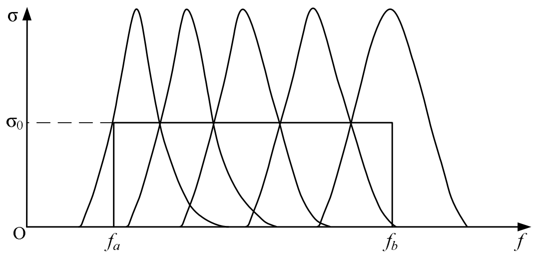



Figure 3. Impact of algorithm for increased jamming bandwidth of chaff

Silk filled the chaff mixed package, the number of wires of different lengths chaff selected determines the best benefit-cost ratio. In order to avoid the waste of silk chaff, chaff should be the maximum effective scattering area exactly twice, and the first kind of chaff wire interference frequency equal to the bandwidth of high frequency interference of the first kind of chaff wires frequency bandwidth of the low frequency end.

Let the length of the first kind of resonance wavelength of chaff wires, number of, interference center frequency, bandwidth, low-end frequency interference, frequency of high frequency interference bandwidths.

By equation (7) to get:

$$2\exp(-(a\lambda_n(f_{na}-c/\lambda_n)/4\sqrt{2}\pi)^2)=1 \quad (8)$$

As well as high frequency of the jamming bandwidth of the n kind chaff wire equal to low frequency of the jamming bandwidth of the n+1 kind chaff wire, so that:

$$\begin{cases} f_{nb}=f_{(n+1)a} \\ f_{nb}=2f_n-f_{na} \end{cases} \quad (9)$$

Of equation (8), (9) order has been:

$$\begin{cases} 2\exp(-(a\lambda_n(f_{na}-c/\lambda_n)/4\sqrt{2}\pi)^2)=1 \\ \sigma_n=2\sigma_0=N_n 0.213\lambda_n^2 \\ f_{nb}=f_{(n+1)a} \\ f_{nb}=2f_n-f_{na} \end{cases} \quad (10)$$

According to information provided against the interference of the radar band and the effective scattering cross-section and other information on the type (10) can be obtained by solving the chaff silk mixed bag filled with various length of wire the length of the chaff and the required number of matching program.

First, calculate the first chaff from the wire half-wavelength resonant wavelength and the interference center frequency, then calculate the number of the kinds of chaff wires. If the chaff wire interference bandwidth to cover the frequency band that is generated wire chaff ratio program to calculate the end; if the bandwidth of the chaff can not interfere with silk band to cover, so that by (8) calculated the second chaff wire half-wavelength resonant wavelength and interference center frequency, frequency band to meet interference requirements, calculate the end, does not meet the above calculation process is repeated until a date to meet the conditions. Finally, according to the interference of the center frequency of chaff silk filament length generated chaff ratio programs; number of chaff wires, respectively.

Widened algorithm flow chart computing the ratio of chaff wires shown in Figure 4:

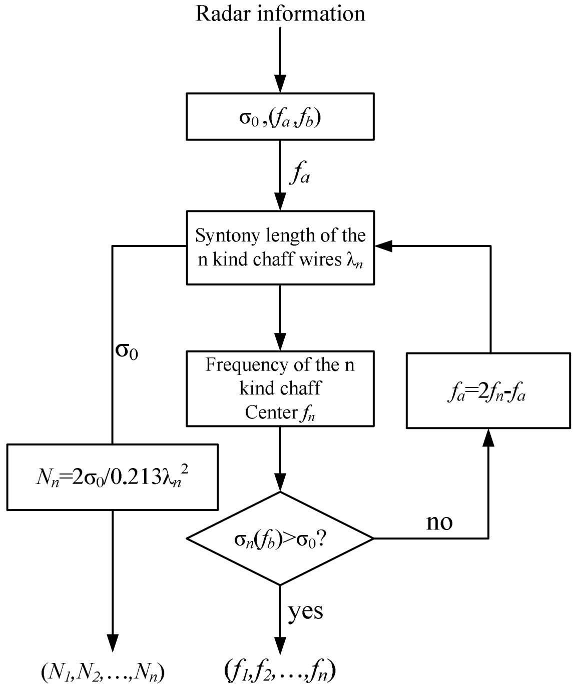



Figure 4. Chaff wire ratio widened algorithm flowchart

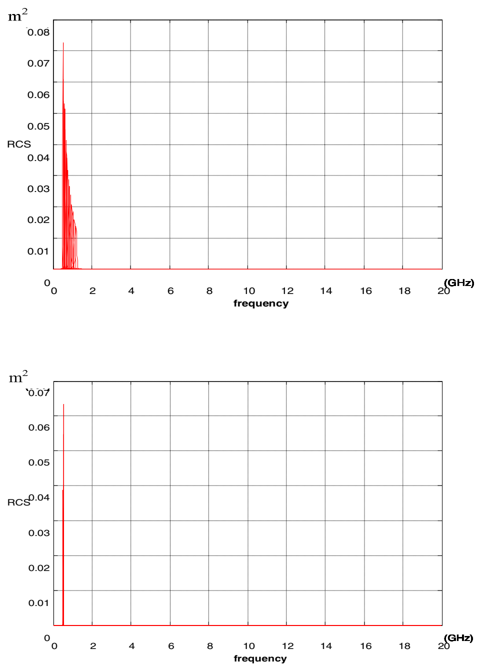
## VI. Simulation Results and Analysis

Surveillance radar according to the hypothesis against the information in the cover of chaff corridor exists on the direction of attack aircraft attack enemy air surveillance, fire control radar, radar frequency band covered by L, S, C, X four working band. According to operational mission requirements, to be laid at 100km away from the radar chaff corridor, the corridor could interfere with the chaff in the 0.5GHz to 12GHz frequency bands to be within the bandwidth of the interference, to the reflection area.

By the initial conditions of the specific radar simulation parameters and operational mission requirements, requirements GHz, Simulation using Matlab simulation results obtained are as follows.

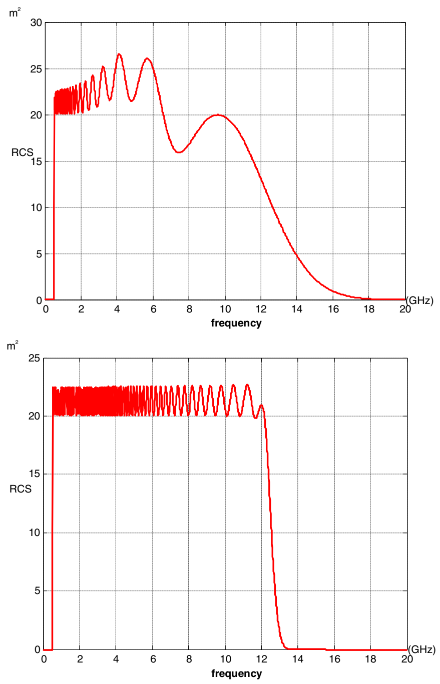
Aluminized glass because of its ease of use, create a simple, cost is relatively inexpensive, passive jamming pod is the most commonly used injected chaff, but the glass of empty aluminum is not a very long time, interference time is relatively shorter effective . In order to increase the effective interference chaff corridors of time, we sometimes put hollow chaff, because of its quality of light, and thus has a longer blank time. Because that the two large differences in the quality of chaff, the chaff computer simulation get a different ratio of silk solution.

Figure 5 (a) install package for the hollow chaff mixed in various length wire chaff chaff's single effective scattering area curve, 5 (b) equipment for the aluminum-glass mixed bag of various lengths of single chaff effective scattering area curve chaff wire, 6 (a) mixing equipment package for the hollow chaff in the total length of the effective scattering area of the curve, 6 (b) equipment for the aluminum-glass mixed bag of various lengths of chaff the total effective scattering area of the curve.




(a) Hollow chaff (b) Aluminum glass chaff

Figure 5. The effective scattering area curve of single chaff wire in the bag filled with Hollow aluminum glass chaff and chaff




(a) Hollow chaff (b) Aluminum glass chaff

Figure 6. Hollow aluminum glass chaff and chaff mixed bag filled with the effective scattering area curve

It can be seen from Figure 5, the interference in the same chaff mixed loading conditions, the length of hollow type of chaff required less, the length of aluminum chaff type of glass needed more; and the center frequency interference the same, relatively hollow glass aluminum chaff interference resonant peak is more sharp, single chaff wire interference bandwidth.

It can be seen from Figure 6, chaff mixed bag of chaff filled wire, the length of hollow type of chaff needed less aluminum chaff length glass types required more; but hollow chaff mixed package of various length wire chaff interference bandwidth is wider, while the aluminized glass chaff mixed bag of various length wire interference bandwidth is narrow. Both the chaff bag filled with silk mixed, are able to reach 0.5GHz interference to 12GHz bandwidth. However, mixed loading of aluminized glass chaff packet interference better, can be achieved from 0.5GHz to 12GHz frequency range completely suppressed, in this frequency range is greater than the suppression factor of 2; and the hollow filled with chaff mixed bag 6.58GHz to 9.62GHz frequency range in the memory area of the gap in the scattering, so that the effective reflection area in the cover of the aircraft penetration, in this frequency range will be less than the suppression factor of 2.

## VII. CONCLUSION

It can be seen from the simulation curve, the interference in the same conditions, to achieve the same interference effect, the quality of heavy chaff required length of more types of quality lighter chaff length of the type required is less. Quality mixed-use loading of the lighter chaff packets will be reduced to some extent the difficulty of producing chaff, the chaff and the quality of light has a longer blank time; and better quality heavy chaff interference effect, but in the manufacturing process requires a higher level. Therefore, when the ratio of chaff mixed silk packaging, should be based on the specific condition of interference by the most appropriate chaff.

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