ANALYZING AND MODELING OF JAMMING DESTROY FACTOR

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Abstract

we build two models of jamming destroy factors by radar and jamming equations, one of jamming destroy factors is calculated for radar efficient echo area and radar receiver, the other is calculated for different swerling case. The method could be used to evaluate jamming effects that anti-jamming measures of frequence agility and low side lobe antenna, when radar are interfered by self defence and stand off jamming of many planes..

1 Introduction

The jamming destroy factor is a index that evaluate noise jamming effect, and its definition is the reduced multiple of radar detection distance with specific jamming condition than without jamming[1].

Usually a method of noise jamming effect evaluation is calculate reject region by jamming equation, and it needs to calculate complicated terrestrial disturbing function. It is not only refer to jammer,radar and covered target parameter, but also refer to configuration position of jammer, and process vast calculation with flight parameter of bandit, and then draw lots of reject region graphics with map[2]. If we consider the difference of radar detection distance in different Swerling case model[3], the reject region is difficult to determine. The other method of noise jamming effect is research tracking error that include angle tracking error and distance tracking error for tracking radar. The tracking error by jamming is related with jamming to signal ratio[4]. The input jamming to signal power ratio is named power suppressing coefficient[5] for get given tracking error. If we choose jamming to signal ratio or power suppressing coefficient to be evaluation criterion of jamming effect[6], should to consider modulation mode,jamming signal quality,radar receiver response characteristic,signal processing mode and so on of jamming signal[7]. It's often difficult to calculation, and even get the result, it is only the radar technology index[8]. And the result can not reflect the change of radar tactics performance after jamming.

Radar power is the important tactics index of radar. When radar suffer noise jamming, signal attenuation and radar power namely detection distance reduce[9]. Because we often need to evaluate the degressive multiple of radar to air target detection distance, it's more efficient that evaluate the jamming effects by degressive multiple of jamming destroy factor namely radar detection distance with special jamming condition than without jamming.

Actually radar maybe face to electromagnetic environment of stand off jamming by many planes and self defence jamming. In this paper we build two models of self defence and stand off jamming by many planes, and consider the jamming destroy factor when frequence agility, low side lobe antenna and so on anti-jamming measures are adopted in radar.

1.1 Mathematical model of Doppler noise jamming effect evaluation

The degressive multiple of radar to air target detection distance namely jamming destroy factor is:

$$K_d = \frac{R}{R_j} \tag{1}$$

R:detection distance
Rj:radar detection distance with jamming

1.2 Self defence Jamming

Radar detection distance without jamming is[10]

$$R=[\frac{P_t G\lambda^2}{(4\pi)^2 kTBFL}\sigma]^{\frac{1}{4}} \quad (2)$$

However, jammer usually know the particular technology parameter of radar difficultly, the target maximum detecting distance with special radar effective sectional area σ_b can be got only, and it is

$$R_{\max}=[\frac{P_t G\lambda^2}{(4\pi)^2 kTBFL}\sigma_b]^{\frac{1}{4}} \quad (3)$$

We can get radar distance four roots and radar effective sectional area is direct ratio, radar detection distance without jamming is

$$R=(\frac{\sigma}{\sigma_b})^{\frac{1}{4}} R_{\max} \quad (4)$$

σ: radar effective echo area;

R_{max}: target maximum detecting distance when radar effective echo area is σ_b;

R: target maximum detecting distance when radar effective echo area is σ;

When we do not consider lose and other factors, radar detection distance with jamming is:

$$R_j=\frac{4\pi R^2}{\lambda}\sqrt{\frac{P_{\min}}{A_N G\Delta f_p}}. \quad (5)$$

G:radar gain;

Δf_P:passband bandwidth of suppressed radar receiver(Hz);

A_N:jammer radiated noise power density(W/Hz);

P_{min}:radar receiver sensitivity;

λ: wave length of radar carrier frequency.

We can calculate jamming destroy factor by Eq.(1) and Eq.(3).

Lots of parameters are not considered in modeling, they are simplified and applicable to self defence jamming of one plane. If we know particular technologu parameter of radar, we can calculate radar detection distance of different Swerling case model and self defence and stand off jamming are concurrent, as well as jamming destroy factor.

2 Stand off/self Defence Jamming

Radar detection distance without jamming is [11]:

$$\log\frac{R}{R_c}+\frac{1}{4}\log L_a=0 \quad (6)$$

$$R_c=129.2[\frac{P_t G_t G_r \tau_\mu \sigma}{f^2 T_S L_R}]^{1/4} 10^{-D_i(n)/40} \quad (7)$$

make

R: detection distance(sea mile);

P_t: radar peak value power(KW);

G_t: radar transmitting antenna gain;

G_r: radar receving antenna gain;

τ_μ: radar pulse width(us);

σ: radar cross section, RCS(m^2)

f:radar frequence(MHz);

T_s: nput noise temperature of efficient system(°K);

L_R: radar lose;

L_a:lose of atmosphere and rainfall;

$D_i(n)$: appropriate testing factor indiated by dB with right Swerling case model P_d,P_{fa}[12]and pulse accumulation number(we can use PRF to Doppler bandwidth ratio to calculate efficient coherent pulse number for Doopler radar).

We can calculate distance value until get non-linear equation of Eq.(4) and Eq.(5), and use Newton recursion fomular repeatedly until relative distance value lass than 0.1km.

radar detection distance with jamming R_j[13]:

$$\log\frac{R_j}{R_c}+\frac{1}{4}\log(1+a/L_a+b)=0 \quad (8)$$

make

$$a = \frac{R_o}{R_{sso}};$$

$$b = \sum_{i=1}^{n} \frac{R_o}{R_{sooi}}$$

$$R_j = \frac{R_c}{[1 + \frac{1}{L_a}[\frac{R_o}{R_{sso}}]^4 + \sum_{i=1}^{n}[\frac{R_o}{R_{sooi}}]^4]^{1/4}} \quad (9)$$

then

$$R_{sso} = 4.816 \times 10^{-3} [\frac{P_t G_t G_r \tau_\mu \sigma}{P_j G_j L_j}]^{1/2} \quad (10)$$

$$R_{sooi} = (R_j R^*_{ssoi})^{\frac{1}{2}} [\frac{G_r}{G_{rj}}]^{1/4} \quad (11)$$

$$R^*_{ssoi} = 4.816 \times 10^{-3} [\frac{P_t G_t G_r \tau_\mu \sigma}{P'_j G'_j L'_j}]^{1/2} \quad (12)$$

where

P_j:jammer noise frequency spectrum density (W/Hz);

G_j:jammer antenna gain at radar direction;

L_j:power lose of attenuation between jammer transmitting power measuring point and radar antenna end.

R_{sso}:radar detection distance with self defence only and S/N=1;

R_{sooi}: radar detection distance for every stand off jammer;

G_{rj}:radar antenna gain at jammer direction;

R_j:distance between radar and jammer;

P'_j:jamming power density of stand off jammer (W/Hz);

G'_j:antenna gain of stand off jammer (dB);

L'_j: stand off jammer lose (dB)。

We can use Newton recursion fomular repeatedly. If there are not self defence jamming then make a=0 in Eq.(10); if there are not stand off jamming then make b=0 in Eq.(10); finally we can get radar distance with jamming.

3 Simulation by MATLAB

We simulate by MATLAB[14], and input jammer and radar parameters by menu, the parameters include radar frequency sgility and side lobe gain of receiver antenna that consider low side lobe antenna. The parameters of stand off jamming are inputted by vector, each jammer parameters are different, and vector length equal to stand off jammer number.

We build simulation program as follow:

(1)testing factor simulation program

Pulse accumulation number is a important factor when we calculate testing factor. We can use PRF to Doppler bandwidth ratio to calculate efficient coherent pulse number for pulse Doopler radar. The incoherent pulse accumulation number is determined by pulse total number that radar beat down on target divided by efficient coherent pulse number. For a non-doppler radar, Doppler bandwidth equal to radar PRF, therefore all pulses accumulate by incoherent pulse. We calculate frequency agility radar accord with independent irradiation pulse number, because reduce of case echo undulation lose in Swerling Ⅰ and Swerling Ⅱ and independent irradiation pulse number in direct ratio. Jamming bandwidth must be adjusted to large than radar frequency agility bandwidth. For target detection, independent irradiation pulse number calculation is

$$n_e = 1 + \frac{2L\Delta f}{C} \quad (13)$$

Where L is target length; Δf is frequency agility bandwidth; C is velocity of light.

(2)Effect of atmosphere and rainfall simulation program

We can calculate radar distance without jamming in atmosphere and rainfall from the coefficient list of program storing[15].

(3)stand off jamming simulation program

Calculating radar distance with stand off jamming.

(4)jamming effect simulation program

We calculate radar detection distance with self defence jamming, analyse, self defence/stand off jamming effect. The bar chart shows radar detection distance with jamming and without jamming in different Swerling case model, and then print out the radar detection distance with atmosphere and meteorology attenuation and jamming condition in different Swerling case model.

4 Application

After we program mathematical model by MATLAB[16], we calculate jamming destroy factor of airborne PD radar with Doppler noise jamming, and get curves of Doppler noise power density –jamming destroy factor and radar detection distance, as shown as Fig.1. The Fig.1 shows that Doppler noise power density and jamming destroy factor change in direct ratio, radar detection distance in inverse ratio.

The bar chart of Fig.2 shows that distance without jamming(the first vertical linear per seven group) and with jamming(the second vertical linear per seven group) and jamming destroy factor(the third vertical linear per seven group) in Mathematic model of stand off jamming in different Swerling case model. It obvious that jamming destroy factors in different Swerling case model are same, and we do not consider Swerling case model in self defence jamming mathematic model but we can use it evaluate jamming effect. Fig.3 is accord with Fig.1, and Doppler noise power density and jamming destroy factor change in direct ratio and radar detection distance in inverse ratio with stand off jamming.

5 CONCLUSION

The method of using jamming destroy factor evaluate Doppler noise jamming effect is excellent for little parameters, simplified calculation,practicality and so on.

Although this method only give an example of PD radar jamming destroy factor model with Doppler noise, the calculation refer parameters of noise frequence spectrum density, sensitivity and pass band bandwidth of radar receiver and so on. Therefore this method is applicable to evaluate various niose(amplitude modulation and frequency modulation) jamming airbone pulse and pulse Doppler radar effects.

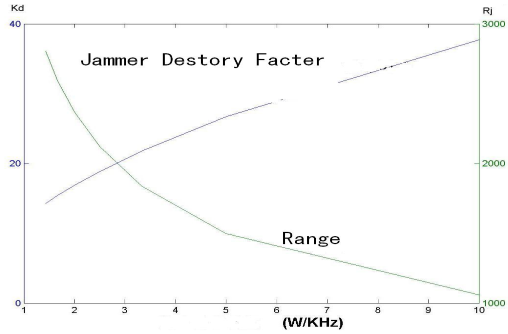

Fig1. Relation of A_N and Kd,Rj with self defence jamming

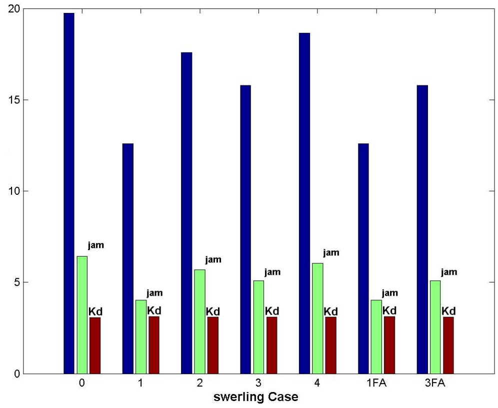

Fig2. Relation of R,Rj and Kd with stand off jamming

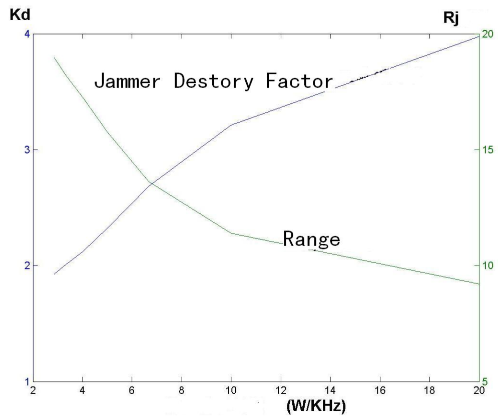

Fig3. Relation of P'_j and Kd,Rj with stand off jamming

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