Research on Millimeter Wave Fuze Echo Signal-to-Noise Ratio under Projectile Motion

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Abstract: In order to calculate the millimeter wave proximity fuze echo signal to noise ratio accurately,analyzes the factors that influence the motion of the projectile fuze echo signal to noise ratio of fuze and target distance, fuse and target grazing angle and target to the scattering characteristics and other factors with the projectile motion of fuze echo signal to noise ratio influence. Finally, make the simulation analysis. The simulation results show that the projectile motion of fuze echo signal-to-noise ratio influence must be considered in design of fuze optimal signal processor.

Introduction

Active millimeter wave fuze using radar system,through the transmitting antenna send active millimeter wave signal to the target, receiving antenna receive target's echo signal, which is processed by the signal processor and generate fuze initiation instructions. Thus, echo signal quality directly influence fuze detonating performance in analysis and evaluation of fuze echo signal quality and signal to noise ratio is a key index. Relevant data show that[1], the echo signal to noise ratio mainly depends on the distance of fuze and target, the fuze launch signal and target of the grazing angle and target to scattering characteristics and other factors. Projectile toward its target, these factors change in time, when the study of fuze echo signal to noise ratio, we must study of projectile motion when the factors of fuze echo signal to noise.

Fuze echo SNR analysis with projectile motion

The fuze antenna configuration and beam pointing

In order to increase the fuze target detection distance, usually the fuze antenna configuration on the head of the body, emission antenna beam center and projectile axis consistent, specific configuration effects such as shown in Fig 1, which, a is fuze antenna beam center and ground grazing angle, b is fuze beam width, q is fuze incident angles.

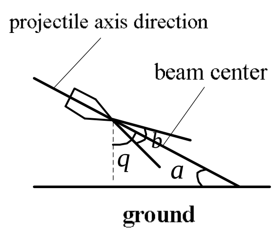
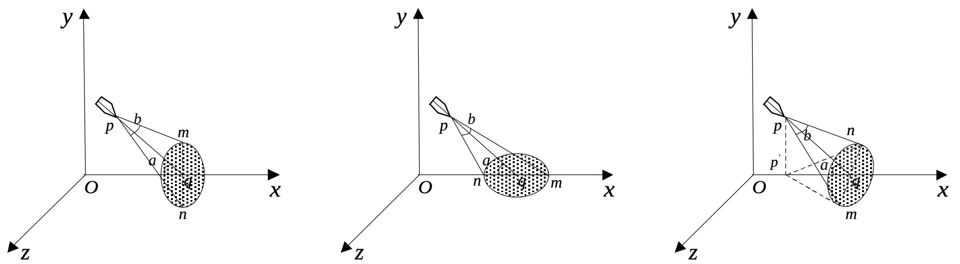


Fig.1. Schematic diagram of the fuze antenna configuration and beam pointing

Analyze fuze grazing angle with the movement of projectile

In order to facilitate the research, the rules in Fig 2 (a), to the major axis of the ellipse mn connection with Ox shaft vertical projection of 0 degrees,fuze with the projectile motion process, fuze antenna beam projection change. Axis of projectile angle a with the ground, due to antenna beam center and the body axis coincidence, therefore, fuze antenna beam center and ground grazing angle for a .



(a)projection 0 degrees (b)projection 90 degrees (c)arbitrary angle projection

Fig.2. Schematic diagram of the fuze beam projection

The fuze antenna beam and ground projection can be divided into the following three conditions:

□The projection of 0 degrees,composed of fuze antenna beam plane pmn and Ox axis angle is a ,as shown in Fig 2(a).

□The projection of 90 degrees, $\angle Onp = a + \frac{b}{2}$, $\angle Omp = a - \frac{b}{2}$,the maximum grazing angle is $a + \frac{b}{2}$, as shown in Fig 2(b).

□Arbitrary projection angle, the point p to xoz plane projection, projection point p' ,the largest grazing angle is a ,as shown in Fig 2(c).

Backscattering coefficient with grazing angle variation analysis of Fuze

This part of scholars home and abroad to establish a target model of backscattering characteristics. In contrast, the calculation Ulaby model has higher precision than the Kulemin model.

(1)Ulaby terrain scattering coefficients model

F.T.Ulaby and M.C.Dobson analyzed a lot of ground about the scattering test data,put forward the average backward scattering coefficient of empirical model[5] :

$$s^0 = P_1 + P_2 \exp(-P_3 q) + P_4 \cos(P_5 q + P_6) \quad (1)$$

In the formula, q is the fuze incident angle (rad), $P_1 \sim P_6$ are parameters, can be obtained by fitting the experimental data.

(2)Kulemin terrain scattering coefficients model

The proposed Kulemin model is suitable for frequency in the range of 3~100GHz, the empirical model is as follows[5] :

$$s^0 = A_1 + A_2 \log(y / 20) + A_3 \log(f / 10) \quad (2)$$

In the formula, f is fuze frequency(GHz), ψ is grazing angle(degree), A_1 ~ A_3 are parameters,With different goals and different ground, in which the coefficient of cement floor, height less than 0.5m grassland as shown in table 1.

Table 1 model parameters Kulemin experience

Target type	A_1	A_2	A_3
Cement floor	-49	32	20
The grass height is less than 0.5m	-21	10	6

Echo SNR calculation

The fuze use pulse Doppler radar system, the pulse radar equation is the following form[2]:

$$R_{\max} = \left[\frac{P_{av} G^2 \lambda^2 \sigma D_{PD}}{(4\pi)^3 P_{\min,\min} (S/N) L'} \right]^{1/4} \tag{3}$$

$$(S/N) = \frac{P_{av} G^2 \lambda^2 \sigma D_{PD}}{(4\pi)^3 P_{\min,\min} R^4 L'} \tag{4}$$

According to the target RCS analysis：

$$\sigma = \sigma^0 dA \approx \frac{\sigma^0 R \beta \rho_s}{\sin\theta} \tag{5}$$

Combined formula (4) and (5):

$$(S/N) = \frac{P_{av} G^2 \lambda^2 D_{PD}}{(4\pi)^3 P_{\min,\min} R^3 L'} \frac{\sigma^0 \beta \rho_s}{\sin\theta} \tag{6}$$

In formula, P_{av} is the average sending power of fuze, G is fuze antenna gain, λ is fuze wavelength,R is distance to target, σ^0 is the radar scattering coefficient, β is fuze beam width, ρ_s is the fuze of the radial distance resolution, θ is fuze incident angles, L' is sum of Fuze loss and equipment allowance.

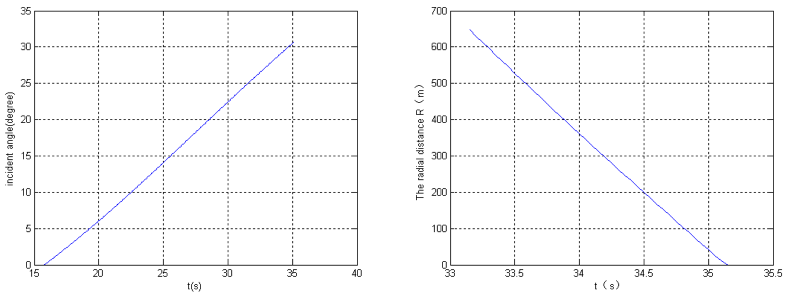
$$D_{PD} = \frac{T_s^2}{T T_g} \tag{7}$$

Among them, T_g is the distance gate, T_s is effective pulse width for the echo. The sensitivity of the receiver $P_{\min,\min} = KT_0 B_N F$, K is Pohl Seidman constant, T_0 is the system temperature, B_N is the equivalent noise bandwidth, F is noise coefficient.

Simulation analysis

Projectile motion simulation

The simulation parameter settings: projectile velocity 950m/s, emission angle of 15 degrees, the initial distance of 0 in X axis and the initial distance of 0 in Y axis.The angle between the axis of projectile fuze and the ground, the fuze and the ground radial distance is simulated,the simulation results are shown in Fig 3.



(a)The descending axis of projectile and the ground angle (b)The fuze and radial distance from the ground

Fig.3. the projectile motion simulation map

Grazing angle simulation of Fuze

The simulation parameter settings: fuze beam width $b = 20^{o}$,fuze simulation with the grazing angle of projectile motion are shown in Fig 4.

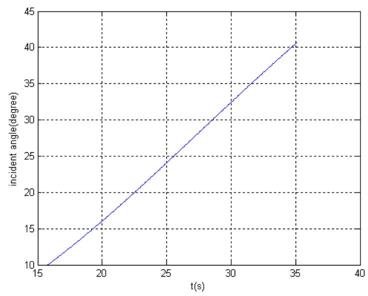
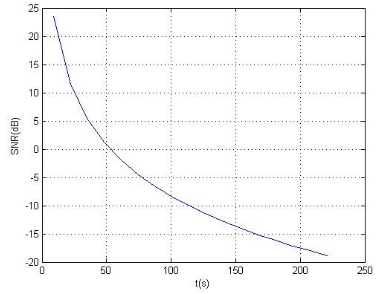
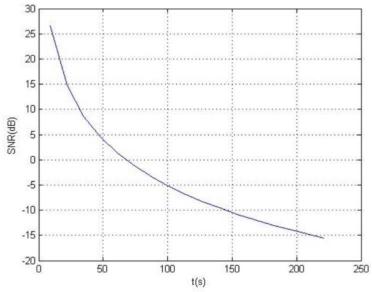


Fig 4 grazing angle fuze simulation map

Fuze echo SNR simulation

Set the main simulation parameters: $P_{av} = 50mW$, G =14dB , l =5mm , b =20° , r_s =3m , $L^{'}$=8dB , T^{0}=300K , $K=1.3806488\times10^{-23}J/K$, F=6dB , $B_N = 50\text{MHz}$。Simulation results is shown in Fig 5.





(a)The cement ground Ulaby model simulation map (b)The grass Kulemin model simulation map

Fig.5. simulation of fuze echo signal-to-noise

Conclusion

The emission of the distance for the fuze and target, the fuze target signal and the grazing angle and the target to the scattering characteristics and other factors of fuze echo signal to noise ratio were theoretical research, and a simulation analysis was carried out. Simulation results show that in the study of fuze echo signal to noise ratio, not only to consider the influence of the above factors, but also consider the impact of different features of fuze echo signal to noise ratio.

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