The Influence of Synchronous Blinking Jamming on Monopulse Radar Seeker Angular Resolution

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Abstract— The Blinking jamming is the intentional and deliberate transmission or retransmission of amplitude, frequency, phase, or otherwise modulated intermittent or pulse signals for the purpose of misleading in the interpretation or use of information by electronic systems. In this paper, it is shown how blinking jamming affects angular resolution of monopulse radar seeker. The analysis is divided to single point and double points according to the Jamming-to-signal ratio .The line-of-sight of the seeker in proportion to jamming-to-signal ratio. The expression from line-of-sight angle to the antenna is obtained. The simulation shows that the resolution angle increases with the jamming power increasing.

Keywords- synchronous; blinking jamming ; monopulse; angle resolution; radar;

I. INTRODUCTION

Monopulse radar systems are quite commonly used, and represent a practical and quick means to improve the accuracy of angular measurements to a fraction of a beamwidth. Monopulse is a simultaneous lobing technique for determining the angle of arrival of a source of radiation or of a target, so monopulse tracking is inherently insensitive to angle deceptive jamming from a single point source. As for the missile, the monopulse radar seeker output is used to measure the trajectory of the missile and to predict future position. Monopulse radar seeker tracking of aircraft formation is performed by use of the echo signals reflected from aircrafts illuminated by the radar transmit pulse.

The blinking jamming is the intentional and deliberate transmission or retransmission of amplitude, frequency, phase, or otherwise modulated intermittent or pulse signals for the purpose of misleading in the interpretation or use of information by electronic systems [1-3]. When several closely grouped aircraft equipped with noise jammers are operating together, as in a coordinated raid, the effectiveness of their jamming may be greatly enhanced by turning each aircraft's jammer on and off sequentially in accordance with a pre-arranged plan[4-7]. The jammer turns and offs with respect to the radar causes the total signal to change with time, resulting in fluctuations in the monopulse radar measurements of the parameters of the target. So, blinking jamming from several closely grouped aircraft causes the centroid of the jamming as seen by the victim radar to oscillate erratically in angle[8-14]. Recently, several new analysises on blinking jamming have emerged. In [11-12], the effect of different blinking frequency on the angle tracking system was simulated and evaluated.

II. THE RECEIVED SIGNALS FORM THE 2-AIRCRAFT FORMATION WITH BLINKING JAMMERS

Monopulse radar seeker tracking of aircraft formation is performed by use of the echo signals reflected from aircrafts illuminated by the radar transmit pulse. Some complicated-targets are so complex that angular glint shows intensive random characteristics. The blinking of echo signal from a complicated-target explained that angular glint is a distortion of the echo signal phase front[2].

The following notations are used throughout this work: $u(t)$ denote the total signals are received by the seeker; $u_k(t)$ denotes the received signal from the aircraft k; U_{p_k} denotes the amplitude of the echo signal from the aircraft k; ω_{P_k} denotes the frequency of the echo signal from the aircraft k; ϕ_{P_k} denotes the phase of the echo signal from the aircraft k; U_{J_k} denotes the amplitude of the jamming signal from the aircraft k; ω_{J_k} denotes the frequency of jamming signal from the aircraft k; ϕ_{J_k} denotes the phase of jamming signal from the aircraft k ; U_k and ω_k denotes the amplitude and the frequency of the received signals from the aircraft k ; J/S denotes the Jamming-to-signal ratio between the jamming signal and the echo signal of the aircrafts . q_1 denotes the line-of-sight angle of the object 1 , q_2 denotes the line-of-sight angle of the object 2.

Figure 1 shows the relationship between the aircrafts and the missile.

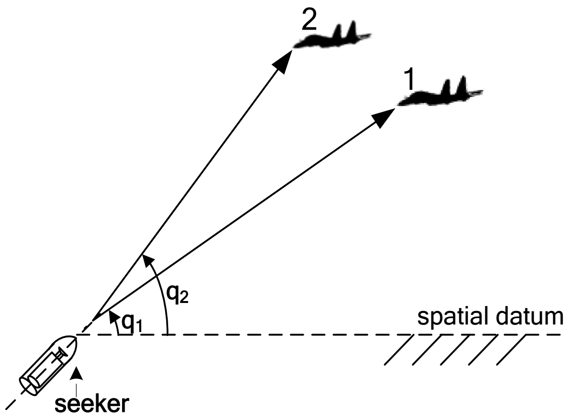

Figure 1. The angle relationship between aircrafts and missile

The blinking jamming is divided into synchronous blinking jamming and asynchronous blinking jamming according to time sequence between the two blinking signals. Figure 2 shows that the Jammers intermittently transmit signals in the process of the synchronous blinking jamming.

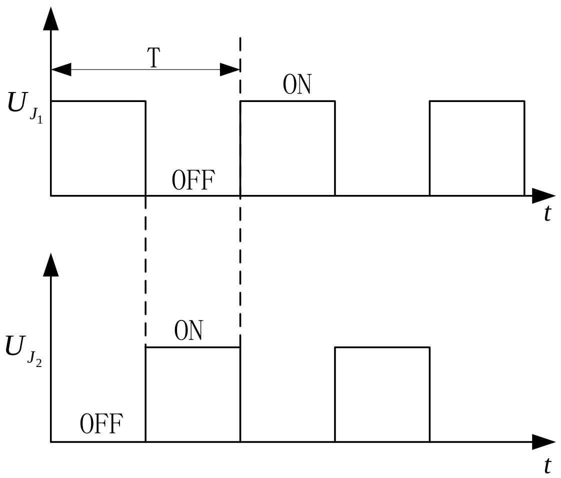

Figure 2. Synchronous blinking jamming

The 2-aircraft formation with blinking jammers is complex in shape. The total signal is composed of the vector sum of a group of superimposed signals from the individual aircrafts. The total signals of the seeker are composed of two components ($u_1(t)$ 、 $u_2(t)$) in the process of the synchronous blinking jamming.

$$u(t) = u_1(t) + u_2(t) \quad (1)$$

Figure 2 shows when the jammer of the aircraft 1 is turned on and the other jammer of the aircraft 2 is turned off.

$$u_1(t) = U_{P_1} \exp i(\omega_{P_1} t + \phi_{P_1}) + U_{J_1} \exp i(\omega_{J_1} t + \phi_{J_1}) \quad (2)$$

$$u_2(t) = U_{P_2} \exp i(\omega_{P_2} t + \phi_{P_2}) \quad (3)$$

$$u_1(t) = U_{P_1} \exp i(\omega_{P_1} t + \phi_{P_1}) \quad (4)$$

$$u_2(t) = U_{P_2} \exp i(\omega_{P_2} t + \phi_{P_2}) + U_{J_2} \exp i(\omega_{J_2} t + \phi_{J_2}) \quad (5)$$

III. MONOPULSE SEEKER LOS ESTIMATION OF SYNCHRONOUS BLINKING JAMMING

The monopulse radar seeker tracking is inherently insensitive to angle deceptive jamming from a single point. This is a result of the monopulse angle-error-sensing mechanism that forms an error proportional to the angle between the target and the antenna's boresight on each return pulse. This is accomplished by comparing signals received simultaneously in two or more antenna beams. The advantages of monopulse radar seeker are as follows: acquiring angular divergence information quickly and disregarding influence of echo-amplitude fluctuation, so monopulse radar system is used widely in many kinds of missile seekers. The radar seeker uses monopulse techniques to measure the target angular displacements. However, when multiple unresolved targets are present, the angular information cannot be extracted correctly. Glint noise can severely degrade the tracking performance. Complex targets can cause irregular electromagnetic wave reflection.

The total signals $u(t)$ from one or two directions according to J/S at any time. The echo signals of the aircrafts are neglected when J/S is far greater than one. Otherwise, the total signal $u(t)$ from the two directions at any time.

A. Jamming power far greater than echo signal

The line-of-sight angle is q_k when the jammer of the aircraft k is turned on and the other jammer is turned off. So, the line-of-sight angle changes between q_1 and q_2 with the jammers are turned on or turned off.

$$u(t) = U_{J_k} \exp i(\omega_{J_k} t + \phi_{J_k}) \big(k = 1, 2\big) \quad (6)$$

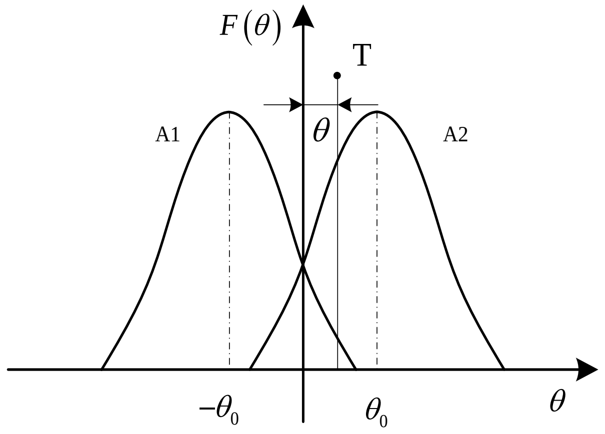

Figure 3. Amplitude-comparison monopulse system

Figure 3 shows a typical amplitude-comparison monopulse system .The input signals of the antenna A and B are expressed respectively:

The sum signal $u_S(t)$ is:

$$u_S(t)=U_{J_k}[F(\theta_0-\theta)+F(\theta_0+\theta)]\cos\omega_{J_k}t \quad (7)$$

The difference signal $u_D(t)$ is:

$$u_D(t)=U_{J_k}[F(\theta_0-\theta)-F(\theta_0+\theta)]\cos\omega_{J_k}t \quad (8)$$

The signal is shifted to an intermediate frequency (IF) by mixing with a local-oscillator frequency.

The sum signal $u_S(t)$ at the IF output:

$$u_S(t)=k_S\left\{U_{J_k}[F(\theta_0-\theta)+F(\theta_0+\theta)]\cos\omega_{IF}t\right\} \quad (9)$$

The difference signal $u_D(t)$ at the IF output:

$$u_D(t)=k_D\left\{U_{J_k}[F(\theta_0-\theta)-F(\theta_0+\theta)]\cos\omega_{IF}t\right\} \quad (10)$$

The detecting voltage u_{pd} is outputed by phase measuring apparatus through Sum-difference processing is:

$$u_{pd}=k'\overline{u_S(t)u_D(t)} \quad (11)$$

$$u_{pd}=k_{pd}\frac{\mu^2\left[F^2(\theta+\theta_0)-F^2(\theta-\theta_0)\right]}{\left\{1+\mu\left[F(\theta_0-\theta)+F(\theta_0+\theta)\right]\right\}^2} \quad (12)$$

The direction finding curve of the monopulse seeker to the single signal $F(\theta)$ is equal to $\sin\left(\frac{\pi D}{\lambda}\sin\theta\right)\Big/\frac{\pi D}{\lambda}\sin\theta$ and $\theta_{0.5}$ is equal to λ/D.

where

λ is wavelength of radiated energy;

D is length of aperture (same units as λ);

$\theta_{0.5}$ is the half-power beam width.

B. Echo signal close to jamming power

The total signals $u(t)$ from the two directions at any time when the echo signals of the aircrafts cannot be neglected.

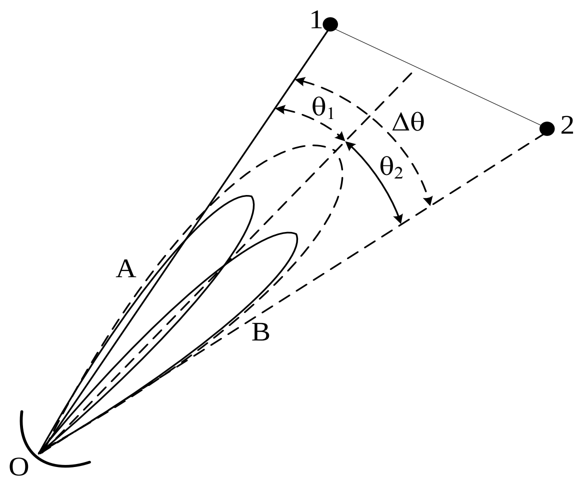

Figure 4. Tracking of amplitude-comparison monopulse to double signals

The input signals of the antenna A and B are expressed respectively:

$$u_A=U_1F(\theta_0-\theta_1)\cos\omega_1t+U_2F(\theta_0-\theta_2)\cos\omega_2t \quad (13)$$

$$u_B=U_1F(\theta_0+\theta_1)\cos\omega_1t+U_2F(\theta_0+\theta_2)\cos\omega_2t \quad (14)$$

The sum signals u_S and the difference signals u_D are given:

$$u_S=u_A+u_B \quad (15)$$

$$u_D=u_A-u_B \quad (16)$$

Where

k_S is the amplified parameters of the sum signal ;

k_D is the amplified parameters of the difference signal ;

ω_{IF} is the intermediate frequency.

The detecting voltage u_{pd} is outputed by the phase measuring apparatus through the Sum-difference processing

$$u_{pd}=k'\overline{u_S(t)u_D(t)} \quad (17)$$

$$u_{pd}=k_{pd}\left\{\left[F^2(\theta_0-\theta_1)-F^2(\theta_0+\theta_1)\right]+a^2\left[F^2(\theta_0-\theta_2)-F^2(\theta_0+\theta_2)\right]\right\} \quad (18)$$

where

k' is a constant;

k_{pd} is a proportion parameter of the phase measuring apparatus.

IV. SIMULAITION

A. *Jamming power far greater than echo signal*

The valid direction finding area is the main direction finding area of the curve (from -1.15 $\theta_{0.5}$ to 1.15 $\theta_{0.5}$). Usually, the peak of the highest auxiliary direction finding area is much lower than the peak of the main direction finding area.

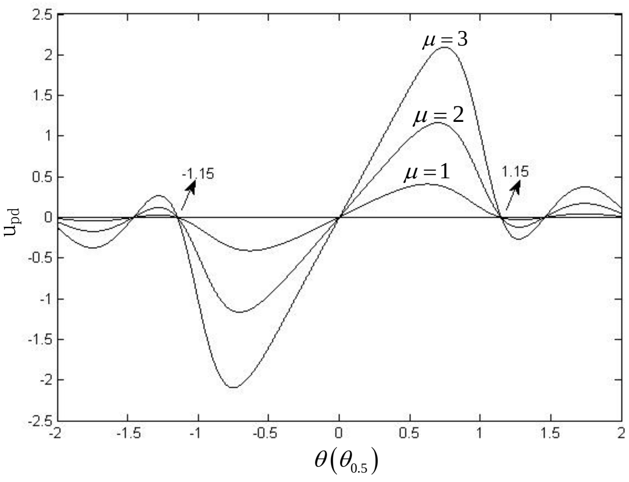

Figure 5. Direction finding curve of monopulse seeker to single source

The line-of-sight angle changes between the angle positions of the two aircrafts in the main direction finding area of monopulse radar seeker. So, the blinking jamming becomes invalid when the jamming signals from the main direction finding area to the auxiliary direction finding area.

B. *Echo signal close to jamming power*

The pointing of the antenna boresight for the DOA estimation of two unresolved signals with equal power.

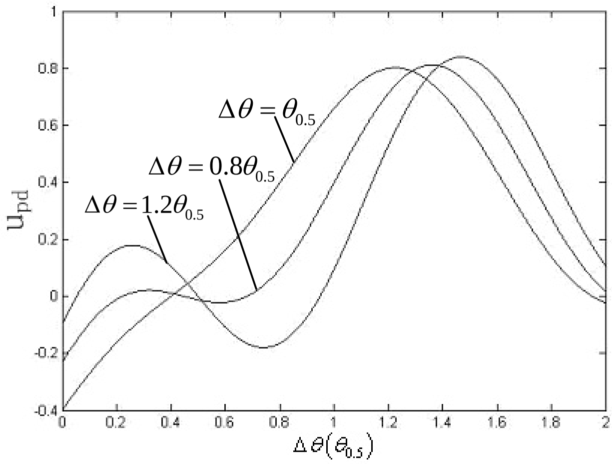

Figure 6. Resolution process of monopulse radar seeker to double signals

Figure 6 shows that two signals cannot be resolved when the angular distance of the aircrafts measured in terms of $0.8\theta_{0.5}$, but two equilibrium points appear when $\Delta\theta$ is equal to $\theta_{0.5}$ .Two signals are distinct from each other when $\Delta\theta$ is equal to $1.2\theta_{0.5}$.

V. CONCLUSION

In this paper, The Synchronous blinking jamming concept and model are analyzed in part two. The total signals $u(t)$ of the 2-aircraft formation with jammers are analyzed in part three. The analysis is divided to single point and double points according to the Jamming-to-signal ratio. The simulation result shows the relationship between the angular resolution and blinking jamming frequency.

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