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DECOY TECHNIQUE WITH TWO-POINT SOURCE IN COUNTERMEASURES AGAINST ANTI-RADIATION MISSILES

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Abstract: This paper gives a brief discussion of the principle of investigating ARM [anti-radiation missile] with coherent or noncoherent dual-sources (quasi-dual-source). The technique should be used in radar systems. Finally, the formula to derive the optimal distance L_{opt} between two sources is derived, based on which the countermeasures against ARM are proposed.

Key Words: ARM, jamming with a two-point source, guidance head of passive radar.

I. Introduction

Since the emergence of anti-radiation missiles in Vietnam battlefield in 1965, ARM have been rapidly developed, especially after the seventies with the successive emergence of new types of ARM constituting a fatal threat to radar. It is estimated that ARM with artificial intelligence will emerge; this expectation will bring greater threats to radar. Hence, techniques of countermeasures against ARM become an urgent matter at present.

One of the effective technical measures of countermeasures against ARM is jamming with a two-point source; the paper discusses this matter.

II. The Principle of Countermeasures Against ARM by Jamming with Coherent Two-Point Source

Countermeasures of ARM by jamming with a two-point source involves establishing another radiation source O_2 in the vicinity of the radar O_1, which is to be protected; both sources have the same signal frequency with phase coherence. When the phase difference is high, the guidance head tracks a point other than the two points (O_1 and O_2); and it guides the missile to attack this other point. Thus the missile is ineffective.

1. General principle of tracking a coherent two-point source with the guidance head

If the passive radar guidance head is a single pulse heterodyne type, sum to difference ratio amplitude system, refer to Fig. 1 for its block diagram of its principle.

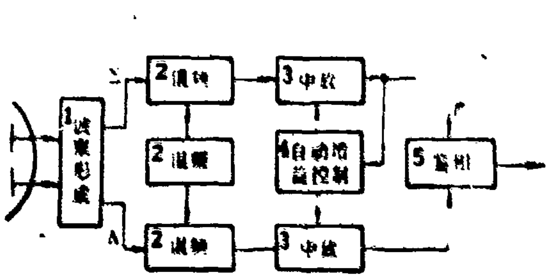

Fig. 1. Principal block diagram of passive radar guidance head
Key: 1. Formation of wave beam 2. Mixing (frequency) 3. Intermediate amplification 4. Automatic gain control 5. Phase discrimination

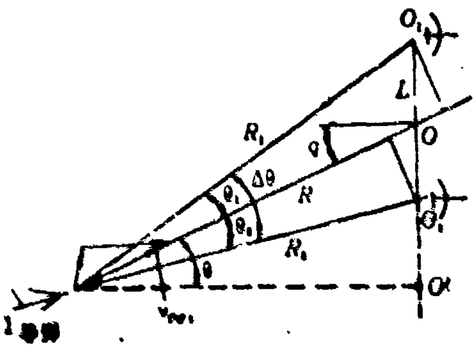

Fig. 2. Diagram showing the relative positions of the missile and the two-point source
Key: 1. Missile

Fig. 2 shows the relative positions of a two-point source and the missile. Signals of two-point source radiation are, respectively, $U_1\cos(\omega t+\varphi_1)$ and $U_2\cos(\omega t+\varphi_2)$. θ_0 is the included angle between the peak value point and the aiming axis in the antenna radiation pattern of the guidance head; $\Delta\theta$ is the visual angle of the guidance head relative to the two-point source. θ is the included angle between the aiming axis and the center line of the two-point source.

There are some situations for two-point phase coherent source jamming radar in far field as that analyzed in [3]; thus, the formula for tracking angle of a two-point source with the guidance head can be derived:

$$\vartheta=\frac{\Delta\theta}{2}\frac{1-\beta^2}{1+\beta^2+2\beta\cos(k(R_1-R_2)+\phi)} \quad (1)$$

In the equation, $\beta=\frac{U_2}{U_1}$, $k=\frac{2\pi}{\lambda}$; R_1 and R_2 are, respectively, the direct line-of-sight distance of the missile to targets O_1 and O_2. $\varphi=\varphi_1-\varphi_2$.

When $kR_1=kR_2+2m\pi$, $\vartheta=\frac{\Delta\theta}{2}\frac{1-\beta}{1+\beta}$ (2)

When $kR_1=kR_2+2m\pi+\pi$, $\vartheta=\frac{\Delta\theta}{2}\frac{1+\beta}{1-\beta}$ (3)

When $kR_1=kR_2+2m\pi+\phi$, $\vartheta=\frac{\Delta\theta}{2}\frac{1-\beta^2}{1+\beta^2+2\beta\cos\phi}$ (4)

Referring to the above, m is an integer (m = 1, 2, 3, and so on).

From Eq. (3), when the phase difference of the composite signal is π for the two-point source on the plane of antenna aperture, the guidance head tracks a point other than the two-point source.

On steady approach to the target by the missile, the guidance head enters the near field of the two-point source from the far field, the tracking characteristics vary with the variation of the distribution properties of the composite field. Therefore, it is required to analyze the distribution characteristics of the composite of the coherent two-point source.

2. Distribution characteristics of composite field of the coherent two-point source in space

(1) Space composite field: as is well known, the coherent two-point source will certainly form multiple wavebeams of grid lobe shape in space. The number of grid lobes is $M=2\left[\frac{kL-\varphi}{2\pi}\right]$ (the bracket indicates the nearest integer is presented). The width of the wavebeam for the grid lobe is $\theta_{\bullet} = \frac{\pi}{kL\cos\theta_{\bullet}} \approx \frac{\pi}{kL} = \frac{\lambda}{2L}$; by using the procedure flow diagram as shown in Fig. 3 (a), the phase properties of the composite field can be calculated as the curve group shown in Fig. 3 (b). We can see from the figure that the phase difference between two wavebeams is π, and the phase variation is linear. We also see that a phase linear inclination exists in the nondistortion zone (within the wavebeam), but its inclination is relatively low.

(2) Angle width in the distortion zone

The width is the distortion zone is an important parameter to determine the tracking characteristics; the width is expressed with θ_W; θ_W is the angular distance of two intersecting points between the tangent of the phase curve of the distortion point and the tangent of the phase curve of two adjacent nondistortion points. Through analysis, the angular widths in the distortion zone can be obtained as

$$\theta_{\bullet} = \frac{\pi}{kL\cos\alpha}\,\frac{\beta-1}{\beta} \tag{5}$$

3. Missile tracking characteristics of a two-point source: because of the alternating existence of the distortion zone and

the nondistortion zone, missile tracking is relatively complex. If the missile is in the distortion zone, it tracks the direction of the normal of the tangent of the phase characteristic curve; that is, the missile tracks a point other than the two-point source. However, since the distortion zone is very narrow, the missile quickly penetrates the distortion zone and enters into a nondistortion zone; because of $L \gg \lambda$, the wavebeam of the nondistortion zone is also relatively narrow, and the phase linear inclination also exists. Then the missile will penetrate the wavebeam and enter another distortion zone. Thus, by the alternating penetrations of wavebeams and the distortion zones, it follows a tracking property as shown in Fig. 4.

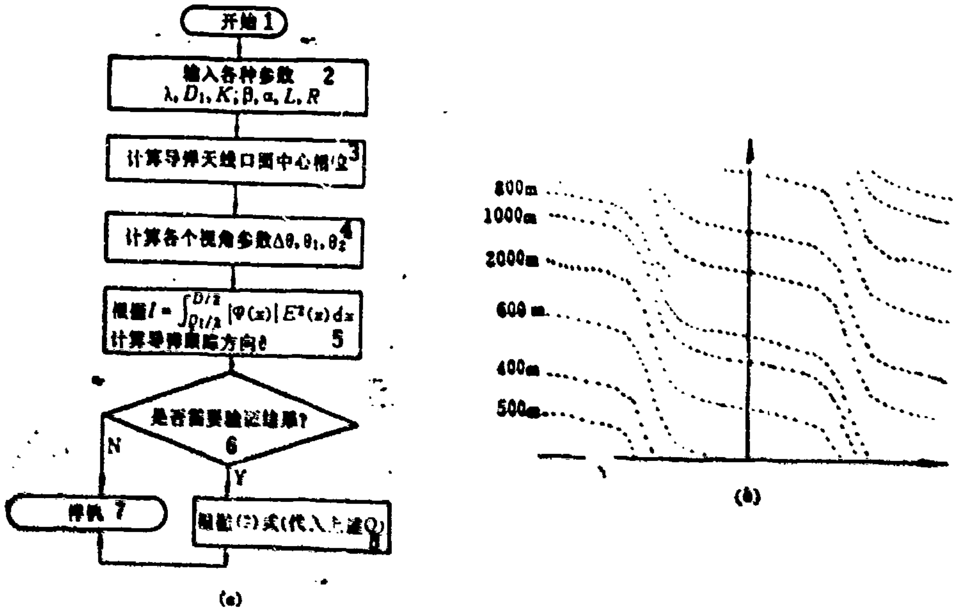

Fig. 3. Procedure flow diagram and phase characteristic curves
Key: 1. Beginning 2. Input of various parameters 3. Calculated phase at center of plane of missile antenna aperture 4. Calculated parameters of visual angles 5. Calculation of missile tracking direction ϑ according to $\int_{D_1/2}^{D/2} |\varphi(x)| E^2(x) dx$
6. Are verification results required or not? 7. Stop the machine
8. According to Eq. (3), for substitution of Q as stated above

From Eq. (5), we know that θ_w can be wide only when β is very large. The tracking tends to a point other than the two sources; however, it is very difficult to implement. Hence, there is no positive conclusion on the jamming effect of the coherent two-point source. Therefore, the coherent two-point source is usually not adopted, but the noncoherent two-point source is adopted.

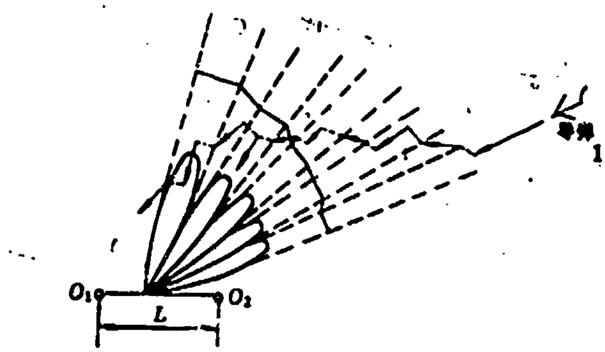

Fig. 4. Schematic diagram showing missile of a noncoherent two-point source
Key: 1. Missile

III. The Principle of Countermeasures against ARM with a Noncoherent Two-Point Source

So-called countermeasures with a noncoherent two-point source amount to similarly establishing a radiation source O_2 in the vicinity of the radar O_1 to be protected. The carrier frequencies of O_1 and O_2 are the same but noncoherent in phase. The guidance head tracks the power center of O_1 and O_2. Thus, the missile fails because it attacks this point.

1. The principle of guidance head tracking of a noncoherent two-point source

The situation of guidance head tracking of a noncoherent two-point source in the far field is the same as the situation of tracking a noncoherent two-point source by single pulse radar as described in [3]. The goniometric equation is

$$u_{\gamma d}=4K_{\gamma d}F'(\theta_0)(\vartheta(1+\beta^2-\Delta\theta)) \qquad (6)$$

the tracking angle ϑ is

$$\vartheta=\frac{\Delta\theta}{1+\beta^2} \qquad (7)$$

When $\beta=1$, the $\vartheta=\frac{\Delta\theta}{2}$ missile tracks the power center of two sources.

With the continuous approach of the target by the target, the included angle $\Delta\theta$ of the O_1 and O_2 of a two-point source relative to the guidance head antenna continuously increases; the inclination of the direction-measuring characteristic curves travels with increase in $\Delta\theta$. When $\Delta\theta=0.9\Delta\theta_*$ ($\Delta\theta_*=0.9\theta_{0.5}$ is the resolving angle of the guidance head antenna), the tracking of the guidance head is in the state of indifferent equilibrium. At that time, the guidance head begins to discriminate the target. Because of jamming by certain factors for tracking a target O_1 or O_2, the guidance head steadily tracks O_1 or O_2 when $\Delta\theta>\Delta\theta_*$. By utilizing the SY-2G passive radar guidance head, the authors conducted tracking experiments toward O_1 and O_2. When $\Delta\theta<\Delta\theta_*$, the guidance head steadily tracks the power center of O_1 and O_2. When $\Delta\theta>\Delta\theta^*$, the guidance head steadily tracks O_1 or O_2. Thus, the above-mentioned conclusion is verified.

Since the volume of the missile is finite, the antenna aperture cannot be made very large; then, the resolving angle $\Delta\theta_*$ of the guidance head is relatively large. Only when the missile is very close to the power center O of the two-point source, does the state of $\Delta\theta=0.9\Delta\theta_*$ exist. In addition, since the maximum overloading of the missile capacity is finite, the guidance head also begins to discriminate the target yet the missile is unable to deflect its direction in time before hitting the center or the power center of the two sources.

To ensure the existence of the state of $\Delta\theta = 0.9\Delta\theta_s$ when the missile is very close to the power center of the two-point source, it is necessary to select the appropriate distance L between the two sources, or called L_{opt}. Hence, L_{opt} becomes one of the important parameters of implementing countermeasures against ARM with a noncoherent two-point source.

2. Selection of the optimal distance L_{opt} of a noncoherent two-point source

Generally, attack by an ARM against a radar is from overhead (such as Hamu [transliterated] and Alamu [transliterated]). Therefore, the formula for calculating L_{opt} is derived when the missile tracking state is at the vertical bisector of the connecting line of the two-point source, as shown in Fig. 5 (a).

Assume that the resolving angle of the guidance head is θ_C ($\theta_C = \theta_R$), the maximum overloading coefficient of the missile is ng, its effective radius of destruction is R_d; and the missile flight velocity is v_{rel}.

From Fig. 5 (a), we know:

$$h = \frac{L}{2}\operatorname{ctg}\frac{\theta_c}{2};\quad \int_0^{t_0} v_1(t)dt = h;$$

$$\int_0^{t_0} v_t(t)\,dt = |OC|,\quad v_1(t) = v_{rel}\cos q;\quad v_t(t) = v_{rel}\sin q;\quad q = \frac{1}{2}ngt^2$$

$$|CO| = \frac{L}{2} - \int_0^{t_0} v_{t}(t)dt.$$ Then

$$\int_0^{t_0} v_{rel}\cos\left(\frac{1}{2}ngt^2\right)dt = \frac{L}{2}\operatorname{ctg}\frac{\theta_c}{2}$$

$$\int_0^{t_0}\cos\left(\frac{1}{2}ngt^2\right)dt = \int_0^{t_0}\cos\left(\frac{\pi}{2}\left(\sqrt{\frac{ng}{\pi}}t\right)^2\right)dt = \qquad (8)$$

$$\int_0^{\sqrt{\frac{ng}{\pi}}t_0}\cos\left(\frac{\pi}{2}u^2\right)\sqrt{\frac{\pi}{ng}}du = \frac{1}{k_1}\int_0^{k_1 t_0}\cos\left(\frac{\pi}{2}u^2\right)du$$

in the equation, $u=\sqrt{\frac{ng}{\pi}}t,\ k_1=\sqrt{\frac{ng}{\pi}}$. The integration in Eq. (8) can be written as:

$$\int_0^{k_1 t_0}\cos\left(\frac{\pi}{2}u^2\right)du=\frac{Lk_1}{2v_{r,t}}\,\mathrm{ctg}\,\frac{\theta_c}{2}=C \qquad (9)$$

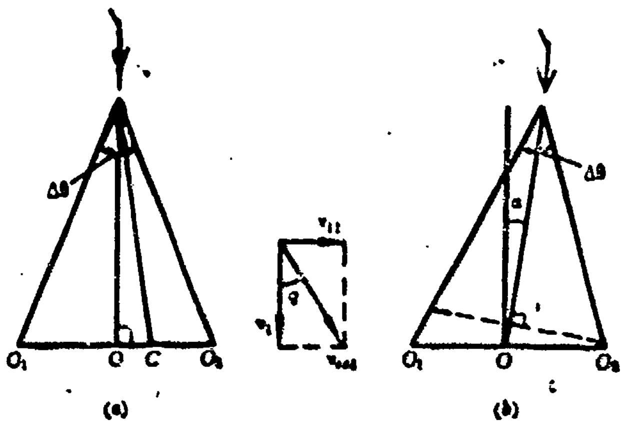

Fig. 5. Schematic diagram for attacking a two-point source by an ARM

The left side of Eq. (9) is a Feinie'er function.

$$|CO_2|=\frac{L}{2}-\int_0^{t_0}v_{r,t}\sin\left(\frac{1}{2}ngt^2\right)dt \qquad (10)$$

$$\frac{\partial|CO_2|}{\partial L}=\frac{1}{2}-v_{r,t}\sin\left(\frac{1}{2}ngt_0^2\right)\frac{\partial t_0}{\partial L} \qquad (11)$$

By differentiating Eq. (9), we obtain

$$\cos\left(\frac{1}{2}ngt_0^2\right)\frac{\partial t_0}{\partial L}=\frac{1}{2v_{r,t}}\,\mathrm{ctg}\,\frac{\theta_c}{2}$$

$$\frac{\partial t_0}{\partial L}=\frac{\mathrm{ctg}\,\theta_c/2}{2v_{r,t}}\Big/\cos\left(\frac{1}{2}ngt_0^2\right) \qquad (12)$$

Substitute Eq. (12) into Eq. (11) and let $\frac{\partial|CO_2|}{\partial L}=0$, then

$$\frac{1}{2}-\frac{1}{2}\mathrm{tg}\left(\frac{1}{2}ngt_0^2\right)\mathrm{ctg}\frac{\theta_c}{2}=0$$

$$ngt_0=\theta_c$$

Then,

$$L_{ext}=\int_0^{\sqrt{\frac{\theta_c}{ng}}}\cos\left(\frac{1}{2}ngt_0^2\right)dt\,2v_{rel}\,\mathrm{tg}\frac{\theta_c}{2}$$

$$=2v_{rel}\,\mathrm{tg}\frac{\theta_c}{2}\sqrt{\frac{\pi}{ng}}\int_0^{\sqrt{\frac{\theta_c}{\pi}}}\cos\left(\frac{\pi}{2}u^2\right)du$$

$$=2v_{rel}\,\mathrm{tg}\frac{\theta_c}{2}\sqrt{\frac{\pi}{ng}}C\left(\sqrt{\frac{\theta_c}{\pi}}\right) \qquad (13)$$

in the equation $C\left(\sqrt{\frac{\theta_c}{\pi}}\right)$ is the Feinie'er function.

$$\frac{\partial^2|CO_2|}{\partial L^2}=-v_{rel}\left(\cos\left(\frac{1}{2}ngt_0^2\right)\frac{\partial t_0}{\partial L}ngt_0+\sin\left(\frac{1}{2}ngt_0^2\right)\frac{\partial^2 t_0}{\partial L^2}\right) \qquad (14)$$

We obtain the following from the differentiation of Eq. (12)

$$-\sin\left(\frac{1}{2}ngt_0^2\right)ngt_0\frac{\partial t_0}{\partial L}+\cos\left(\frac{1}{2}ngt_0^2\right)\frac{\partial^2 t_0}{\partial L^2}=\frac{1}{2v_{rel}}ctg\frac{\theta_c}{2}$$

$$\frac{\partial^2 t_0}{\partial L^2}=\frac{\mathrm{ctg}\frac{\theta_c}{2}}{2v_{rel}\cos\left(\frac{1}{2}ngt_0^2\right)}+\mathrm{tg}\left(\frac{1}{2}ngt_0^2\right)ngt_0\frac{\partial t_0}{\partial L} \qquad (15)$$

By substituting Eq. (15) into Eq. (14), we obtain

$$\frac{\partial^2|CO^2|}{\partial L^2}=-v_{rel}ngt_0\left(\cos\left(\frac{1}{2}ngt_0^2\right)\frac{\mathrm{ctg}\frac{\theta_c}{2}}{2v_{rel}\cos\left(\frac{1}{2}ngt_0^2\right)}+\right.$$

$$\left.\frac{\mathrm{ctg}\frac{\theta_c}{2}\;\mathrm{tg}\left(\frac{1}{2}ngt_0^2\right)}{2v_{rel}ngt_0}+\frac{\mathrm{ctg}\frac{\theta_c}{2}}{2v_{rel}}\mathrm{tg}^2\left(\frac{1}{2}ngt_0^2\right)\right)=-\frac{1}{2}ngt_0\mathrm{ctg}\frac{\theta_c}{2}\left(1+\frac{\mathrm{tg}\left(\frac{1}{2}ngt_0^2\right)}{ngt_0}\right.$$

$$\left.+\mathrm{tg}^2\left(\frac{1}{2}ngt_0^2\right)\right)<0$$

Hence, $|CO_2|$ obtained above is the maximum value.

$$|CO_2|_{ext}=\frac{L_{ext}}{2}-v_{rel}\int_0^{t_0}\sin\left(\frac{1}{2}ngt_0^2\right)dt=\frac{L_{ext}}{2}-v_{rel}\sqrt{\frac{\pi}{ng}}\int_0^{\sqrt{\frac{\theta_c}{\pi}}}$$

$$\sin\left(\frac{\pi}{2}u^2\right)du=\frac{L_{ext}}{2}-v_{rel}\sqrt{\frac{\pi}{ng}}S\left(\frac{\theta_c}{\pi}\right) \qquad (16)$$

In the equation, $S(\frac{\theta_c}{\pi})$ is also Feinie'er function.

The condition of whether there is the effective condition of jamming ARM is

$$|CO_1|_{opt} > R_i \tag{17}$$

When the missile tracking state that the vertical bisectors of the connecting line of the two sources become angle α as shown in Fig. 5 (b), considering that the overhead attack angle α cannot be very large, then based on the sine theorem we obtain

$$\frac{L_{opt}}{\sin(\frac{\pi}{2}-\frac{\theta_c}{2})}=\frac{L_{opt}\ (\alpha=0)}{\sin(\pi-\frac{\theta_c}{2}-\frac{\pi}{2}-\alpha)}=\frac{L_{opt}(\alpha=0)}{\sin(\frac{\pi}{2}-\alpha-\frac{\theta_c}{2})}$$

$$L_{opt,\alpha}=\frac{\sin(\frac{\pi}{2}-\frac{\theta_c}{2})}{\sin(\frac{\pi}{2}-\frac{\theta_c}{2}-\alpha)}L_{opt}\ (\alpha=0) \tag{18}$$

From the derived formulas, we know that L_{opt} can be obtained by only knowing $\Delta\theta_c$, v..., n_g ; however, these parameters can be estimated according to the performance of the ARM.

IV. Technical Measures of Countermeasures Against ARM with Noncoherent Two-Point Source

In addition to rationally selecting L_{opt}, rational selection should be made of the signal carrying frequency, voltage amplitude ratio, modulation parameters, and signal shape of a two-point source in order to execute countermeasures against an ARM. Through experimental methods, the authors propose how to select these parameters.

1. Experimental means

Using an SY-2G passive radar guidance head as the jammed object, two comprehensive measuring and test instruments feed the signals into two trumpets installed on an object simulator to simulate two radiation sources O_1 and O_2. By adjusting the distance between two trumpets, the magnitude of $\Delta\theta$ can be adjusted; a radar comprehensive measuring and test instrument can directly adjust the power magnitude, carrier frequencies, and pulse repetition frequencies of the two sources. A field intensity meter is used to measure and test signal strength in order to determine the value of $\beta = P_2/P_1 = U_2/U_1$. To synchronize sources other than the pulse source, the simultaneous radiation signals of synchronizing two sources are used. By using a two-pulse source, the signal radiation of pulse advance and lagging is implemented. A frequency meter is used to measure and test the carrier frequency of two sources. A pen recorder is used to record the performance curve of tracking.

2. Selection of various types of performance parameters

(1) Selection of two-point source carrier frequency

In passive radar guidance head, there are two operational approaches on the theorem of signal carrier frequency: extension type and narrow-band locking frequency type. The locking frequency has high frequency resolving power, capable of discriminating and tracking a single frequency. The authors conducted frequency tracking experiments by using an SY-2G guidance head with locking frequency loop. The experimental results are as follows: when the difference of two signal frequencies is differing by 1MC, the guidance head only tracks a single target. Actually, it is very difficult to establish a noncoherent two-point source with identical frequency; the frequency difference between them is greater than the discriminating frequency of the guidance head. Thus, countermeasures against ARM are unable to be implemented. Hence, signal carrier frequencies of the two sources should select the rapidly changing frequency, thus causing the guidance head to operate in the form of frequency open loop. Not related to frequency, implementation of ARM is only related to the modulation parameters and ratio of signal versus voltage amplitude.

(2) Selection of amplitude ratio β of radiation signal of two-point source

From the equation $\vartheta=\Delta\theta/(1+\beta)$, we know the power center of two sources tracked by a guidance head. In [3], the relationship curve is also given between the tracking angle ϑ and β. The variation of ϑ with β is relatively large; however, it is not the case that the power center is tracked for any value of β; and it is also not the case that ϑ continues varying for any value of β. By using an SY-2G guidance head, the authors conducted tracking experiments for various β values in two states of open and closed loop of the frequency. It was discovered that when β is greater than 1.25, the guidance head does not track the power center of the two sources, but only tracks the source with the larger tracking power. Sometimes, the guidance head tracks the power center of the two sources, but the guidance head immediately tracks the source with larger power once the disturbance occurs. The experimental results also verified what was pointed out in [6]: for a rapid AGC tracking system for tracking a two-point source, the tracking source will deviate to track the source with larger power because the guidance head is the rapid AGC tracking system, therefore we should select β=1 or $\beta\approx 1$ as shown in the text ($\beta \ngtr 1.2$).

(3) Selection of modulation parameters

Generally, the pulse leading edge tracking and time selection techniques are adopted for a passive radar guidance in order to discriminate and track a single target, countermeasures against multiple-path jamming, jamming of distortion portion signals, and jamming of singular signals; thus, this imposes on the authors the requirement of rationally selecting modulation parameters.

By using an SY-2G guidance head, the authors conducted numerous experiments on various kinds of modulation parameters under two states of open and closed loop of frequency. The experimental results are described as follows:

(a) When the pulse repetition frequencies of two signals are the same but not synchronized, the guidance head only tracks a target, by not tracking the power center of two sources, in the situation of β=1. First, switch on a signal source to let the guidance head to track this target before opening the second signal source; at that time, the guidance head still tracks the first signal source. However, because of switching on of the second source is (relatively speaking) the introduction of noise for the first source, thus the error of angular measurement is increased, and the tracking axis slightly deviates. However, these effects are not large.

(b) For the same pulse repetition frequencies of two signals, the pulse of one signal is always advanced of the pulse of another signal, then the guidance head always tracks that signal source with advance tracking pulse.

(c) In the case of different repetition frequencies of two signals, the guidance head always tracks that signal source with higher repetition frequency.

(d) For the same repetition frequencies of two sources with synchronizing pulse and basically the same front edge, β=1, at that time, the guidance head steadily tracks the power center of the two sources. When a signal source is switched off, the guidance head immediately tracks another signal source. When this signal source is again switched on, the guidance head immediately tracks the power center of these two sources.

The experimental results mentioned above indicate that the following selection should be made on modulation parameters: for the same pulse repetition frequencies of two signal sources with synchronizing operation, the pulse front edge is basically consistent. If variable cycles or sawtooth pulses are adopted, the parameters of these two sources are consistent.

(4) There are three following types for signal form selection of two signal sources:

(a) For pulse signal, the above-mentioned experiments have verified this point.

(b) For continuous wave signals, the authors conducted tracking experiments on continuous wave by using a SY-2G guidance head. Only with the same frequency, $\beta \approx 1$, then the guidance head steadily tracks the power center of these two sources.

(c) In the case of the signal amplitude value as Rayleigh's distribution, the phase is the noise source with homogeneous distribution.

Through analyses and deductions, the tracking voltage of the guidance head tracking of two noise sources is:

$$u_{\cdots} = \frac{r_1+r_2}{2} + \frac{r_2-r_1}{2} \frac{\beta^2-1}{1+\beta^2+2\beta\cos\varphi} \qquad (19)$$

In the equation,

$$r_1 = \frac{F(\theta_0-\theta_1)-F(\theta_0+\theta_1)}{F(\theta_0-\theta_1)+F(\theta_0+\theta_1)}; \quad r_2 = \frac{F(\theta_0-\theta_2)-F(\theta_0+\theta_2)}{F(\theta_0-\theta_2)+F(\theta_0+\theta_2)};$$

$$\beta = \frac{F(\theta_0-\theta_2)+F(\theta_0+\theta_2)}{F(\theta_0-\theta_1)+F(\theta_0+\theta_1)} \frac{U_2}{U_1}$$

Assume that $z = \frac{\beta^2 - 1}{1+\beta^2+2\beta\cos\varphi}$, then we can deduce the following:

$$z = \frac{n-1}{n+1}; \quad n = \frac{P_1}{P_2}$$

; P_1 and P_2 are powers of O_1 and O_2.

$$u_{ost} = \frac{r_1+r_2}{2} + \frac{r_2-r_1}{2} \cdot \frac{n-1}{n+1} \tag{20}$$

From Eq. (20), we can see that the average value of guidance head tracking is always at the power center of a two-point source. When n=1, the tracking is at the power center of two noise sources. By using an SY-2G, the authors conducted tracking experiments on two noise sources; the tracking head steadily tracks the power center of two noise sources (n=1).

V. Conclusions

From the above-mentioned analysis, we know that the apparent effect can be received for noncoherent two-point source countermeasures against ARM only with rationally selecting L_{opt}, $\beta \approx 1$, with the same carrier frequencies and modulation parameters. However, in order to have the power of the attached radiation source the same as the radar, the cost is very high. Therefore, the multiple-point source iterative addition method can be used; this is called the quasi-two-point noncoherent source. If there is a certain attack angle during a missile attack, the method of pulse advance can be adopted to implement jamming with a two-point source. In short, the noncoherent two-point source can be used to implement countermeasures against ARM.

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