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. ISPRJ
ISNPRJ
. ISNPRJ
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Suppress Jamming Technique of Multiple False Targets on Interrupted-Sampling and Non-Uniform Periodic Repeater

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Abstract A multiple false targets method based on interrupted-sampling and nonuniform periodic repeater jamming ISNPRJ and against to the linear frequency modulation LFM pulsed radar with mean level ML CFAR detector is proposed. Firstly the principle is illuminated which takes advantage of the interrupted sampling and repeater jamming IS-RJ to realize the distribution of multiple false targets. After that several key parameters both the number and the SNR of the false targets are derived. Then jamming effectiveness of the ISNPRJ is analyzed on the basis of the mathematics principle of the interrupted-sampling and periodic repeater jamming ISPRJ meanwhile numerical value of the sampling interval the sampling pulse width transmitted pulse width and the transmitted power are calculated. Simulation results show that ISNPRJ can reduce the detection probability of target greatly and jam the radar 's detector effectively.

Key words interrupted-sampling repeater jamming constant false alarm ratio multiple false targets suppress jamming

1 引言

[1~3] .
Roome S J
LFM DRFM
[4] .
. LFM

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LFM [9]

. LFM -

[10,11]

[12].

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[13]. ISRJ

“ ”

[14~18].

14 ~ 18

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ML-

CFAR LFM

ISNPR

.

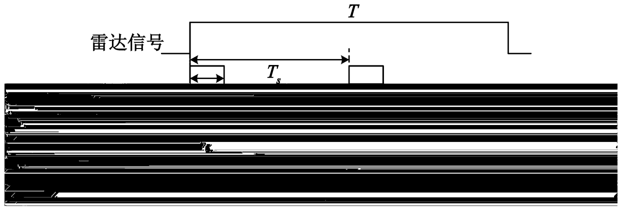
2 间歇采样转发产生多假目标原理

LFM

$$x(t) = \mathrm{rect}\left(\frac{t}{T}\right)\exp\left[\mathrm{j}2\pi\left(f_0 t + \frac{1}{2}k_f t^2\right)\right] \quad (1)$$

T B $k_f = B/T$

LFM $BT >> 1$. 1



$$p(t) = \mathrm{rect}\left(\frac{t}{\tau}\right)\sum_{-\infty}^{+\infty}\delta(t - nT_s) \quad (2)$$

τ T_s .

14 LFM

$$y_s(t) = \sum_{n=-\infty}^{+\infty} y_{sn}(t) = \sum_{n=-\infty}^{+\infty} A_n \mathrm{sinc}\left\{T[k_f(t-T_r)+nf_s]\left(1-\frac{|t-T_r|}{T}\right)\right\} \cdot \exp(\mathrm{j}\pi n f_s t) \quad (3)$$

$\mathrm{sinc}(x) = \sin(\pi x)/\pi x$ $y_s(t)$

nf_s $T_r = T_d + T$

T_d . sinc

n $y_{sn}(t)$

$$T_{sn\_\max} = \frac{-nf_s}{k_f} + T_r = \frac{-nf_sT}{B} + T_r \quad (4)$$

$$|y_{sn}(t_{\max})| = \tau f_s \mathrm{sinc}(n\tau f_s)\left(1 - \frac{nf_s}{B}\right) \quad (5)$$

$n = 0$ $t = T_r$ $y_s(t)$ $|y_s(t)| =$ τf_s $\tau +$ $T_d + T$

$\eta = \tau f_s < 1$

.

3 多假目标压制干扰方法

3.1 对抗场景

2

RCS

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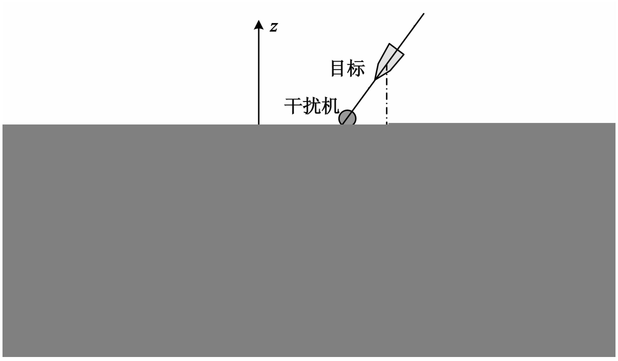
3.2 实现方法

CA-CFAR

GO-CFAR SO-CFAR .



SO-CFAR

CA-CFAR GO-CFAR SO-CFAR

[19]

SO-CFAR .

3 .

1 S_0 $S_{\pm i}$ $i = 1$ 2 … M

2

$\Delta R \leqslant L/2$ ΔR

L . $\Delta R = L/2$

3

.

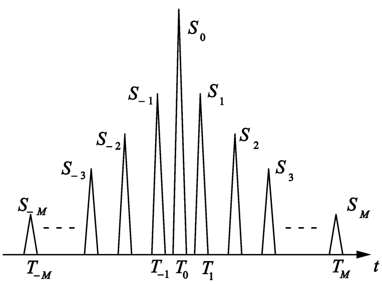


图3 多假目标压制干扰示意图

3.3 参数设计

3.3.1 假目标个数及信噪比

I

[19]

$$\chi_0 = DI \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R_t^4 k T_0 BFL_t} \qquad (6)$$

$D = BT$ I

P_t G_t G_r

λ σ RCS R_t

k T_0

F L_t .

.

$$\chi_m = \eta_m^2 DI \frac{P_j G_j G_r \lambda^2}{(4\pi)^2 R_j^2 k T_0 BF \gamma_j L_j} \qquad m = \pm 1, \dots, \pm M \qquad (7)$$

$\eta_m = \tau_m / T_s$ P_j

G_j γ_j L_j

.

.

$\pm M$

[20]

$$P_d = (1 + T/(1 + \chi_{\text{edge}}))^{-N} \qquad (8)$$

T P_{fa} T

$P_{\text{fa}}(N) = (P_{\text{fa}}^{-1/N} - 1)\chi_{\pm M}$ N

. 20 P_{fa}

P_d

$$\chi_{\text{edge}} \leqslant \frac{(P_d / P_{\text{fa}})^{1/N} - 1}{1 - P_d^{1/N}} \qquad (9)$$

1

Z $N-1$ 1

$$Z = \sum_{i=1}^{N-1} x_i + x_m = Z_1 + Z_2 \qquad (10)$$

$Z_1 \sim \text{Gamma}(N - r, \delta^2)$.

$\alpha = 1$ Gamma α β

$x_m \sim \text{Gamma}(1, \delta^2)$. χ_m χ_{m+1} $10^{\chi/10}$

$\gg 1$ 20 Z

m

$$P_d^m = \frac{2(1 + \chi_m)}{T(P_{fa}, N)\chi_{m+1} + 2(1 + \chi_m)} \qquad (11)$$

$T(P_{fa}, N)$

N $m+1$ χ_{m+1} m

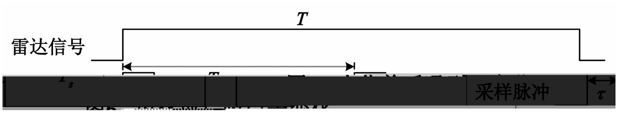
χ_m . $m+1$

$$\chi_{m+1} = \frac{2(1 + \chi_m)(1 - P_d^m)}{T(P_{fa}, N) P_d^m} \quad m = 0, 1, \dots, M-1 \qquad (12)$$

$m=0$ $\chi_m=\chi_0$.
6 χ_0.
9 12
χ_{m+1} $\chi_{m+1}=\chi_M\leqslant\chi_{\mathrm{edge}}$ 2M
.

3.3.2 间歇采样非均匀重复转发参数

. CFAR
L $L=Nc/f_o$ f_o
$L/2$. T
T_s
2M . $T_{d\pm1}\sim T_{d\pm3}$
$T_{dm+1}-T_{dm}=\tau$
.



τ

.

$$y_{\tau_{-3}}(t-T_{d-3})=x_{\tau_{-3}}(t-T_{d-3})*x^*(T-t)$$
$$=x(t)\,\mathrm{rect}\left(\frac{t}{\tau_{-3}}\right)\sum_{n=-\infty}^{+\infty}\delta(t-nT_s-T_{d-3})*x^*(T-t) \quad (13)$$

T_{d-3} 4 T
.
$y_{\tau_m}(t-T_{dm})$ $m=\pm1,\ldots,\pm M$

$$y(t)=\sum_{m=-M}^{-1}y_{\tau_m}(t-T_{dm})+\sum_{m=1}^{M}y_{\tau_m}(t-T_{dm}) \quad (14)$$

2M
τ.

1 τ

CFAR

$$\tau\geqslant L/2\mathrm{c} \quad (15)$$

L c
.
2 T_d
4
R_{jr}
$-M$ $r_{-M}=(M-1)L/2$
$+L/4$ m

$$T_{d_m}=\frac{2R_{jt}}{\mathrm{c}}+2\left(z-M-\frac{1}{2}\right)\tau \quad z=1,\ldots,2M \quad (16)$$

r_{-M} $R_{jt}\geqslant r_{-M}$.
3 τ_m
2

$$\tau_{\pm M}<\ldots<\tau_{\pm1} \quad \frac{\tau_{m-1}}{\tau_m}=\frac{A_{m-1}}{A_m}=\sqrt{\frac{\chi_{m-1}}{\chi_m}} \quad (17)$$

$\tau_{\pm1},\ldots,\tau_{\pm M}$ $A_{\pm1},\ldots,A_{\pm M}$ $\chi_{\pm1},\ldots,\chi_{\pm M}$
.
$L/2$
$\tau_{\pm1}=L/2c$.
4 T_s
2M

$$T_s=T_{d-M}+2M\tau \quad (18)$$

τ T_{d-M}.
5
12 $\chi_{\pm1}$
7

$$P_j=\frac{1}{\eta_{\pm1}^2}\frac{P_tG_t\sigma R_j^2}{4\pi R_t^4G_j}\frac{\gamma_jL_j}{L_t}\frac{2}{T}\left(\frac{1-P_d^0}{P_{fa}}\right)^{N}P_d^0 \quad (19)$$

$\eta_{\pm1}=\tau_{\pm1}/T_s=L/(2\mathrm{c}T_s)$
6 .

5 .

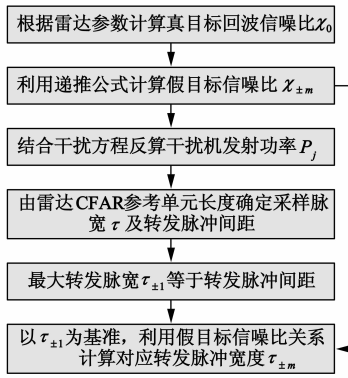


图5 干扰参数计算流程

4 仿真分析

. $P_t = 100\text{kW}$ $G_t = G_r = 30\text{dB}$ $\lambda = 0.1\text{m}$ $T = 20\mu\text{s}$ $B = 10\text{MHz}$ $F = 3\text{dB}$ $L_t = 6\text{dB}$ $T_0 = 290\text{K}$ $D = BT = 500$ $I = 128$ CFAR $N = 8$ $P_{\text{fa}} = 1\text{e}-6$ $T = 36.58$. RCS $\sigma = 10\text{m}^2$ $R_t = 10\text{km} \sim 100\text{km}$ $P_d = 0.1$. $G_j = 10\text{dB}$ $R_{jt} = 1\text{km}$ $\gamma_j = 6\text{dB}$ $L_j = 6\text{dB}$ τ T_s τ_m T_{dm} P_j. 6

χ_0 R_t 6 R_t .

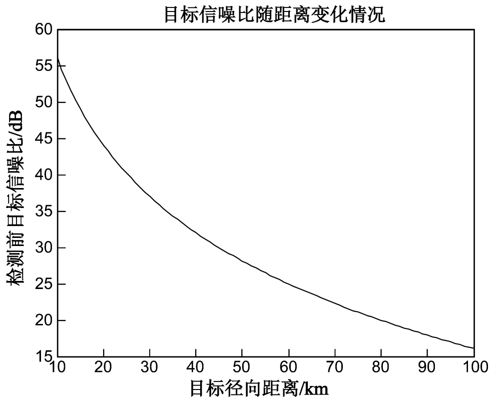


图6 真目标信噪比

7 $2M$ R_t

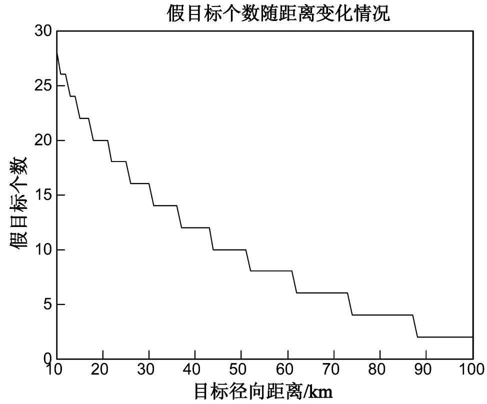


图7 假目标数量

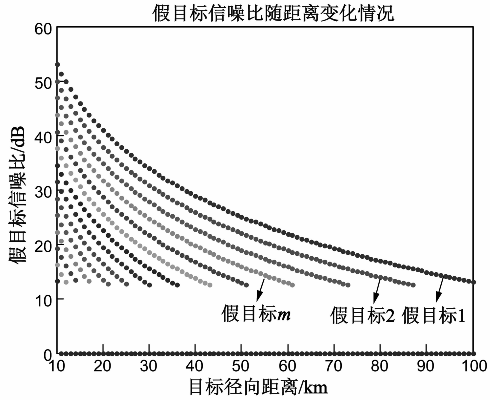


图8 假目标信噪比

8 χ_m R_t . . 13dB.

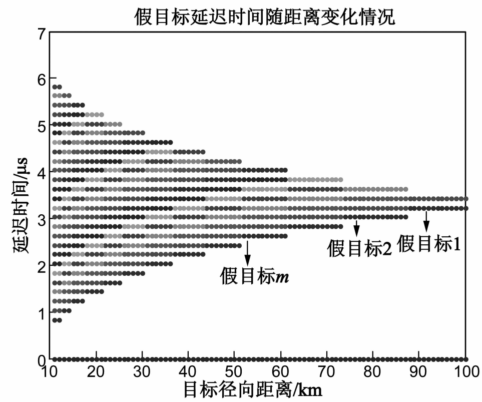


图9 假目标延迟时间

9 T_{dm} R_t R_{jt} .

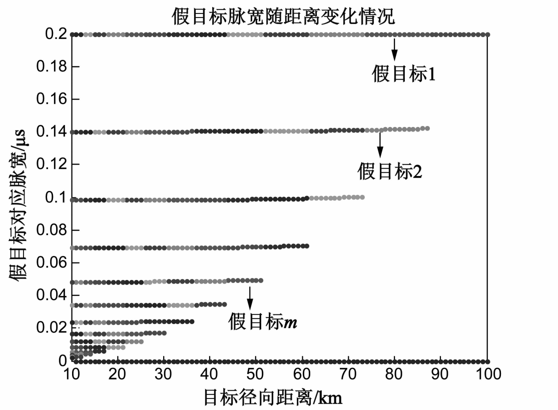


图10　假目标转发脉冲宽度

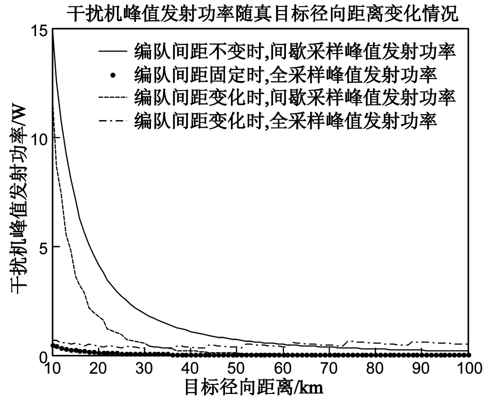


图12　干扰机峰值发射功率图

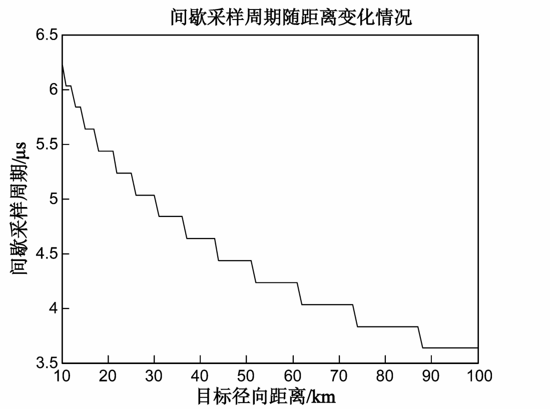


图11　干扰机间歇采样周期

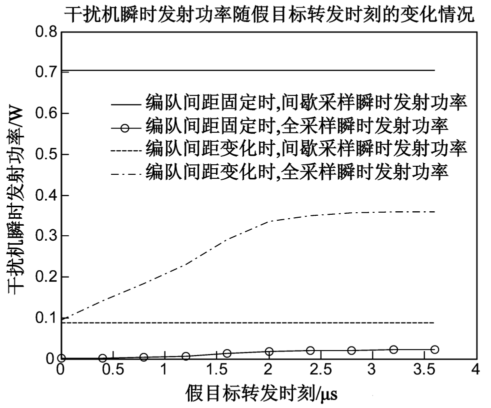


图13　干扰机不同转发时刻的瞬时功率

R_{edge_jt} . 10

T_s R_t

. 11

R_t

.

1 R_{jt}

1000m 2 R_{jt} R_t

. $R_{edge\_jt} = 30m \sim 810m$

$R_{jt} = R_{edge\_jt} + 60m = 90m \sim 870m$ 2 R_{jt}

1.

12 R_t

DRFM

. 2 R_{jt} 1

2

2

2

2

.

R_{jt}

R_{jt}

R_{jt}.

13 $R_t = 50km$

. 10

15W R_t

.

7 9 11 13

R_{jt}

R_{jt}.

ISNPRJ

. 14

ISNPRJ

SO-CFAR 1000

monte carlo .

.

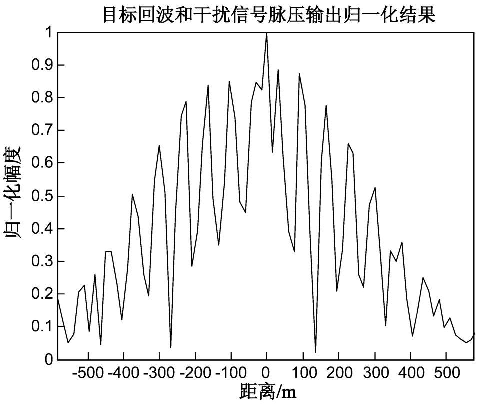


图14 合信号脉压输出结果

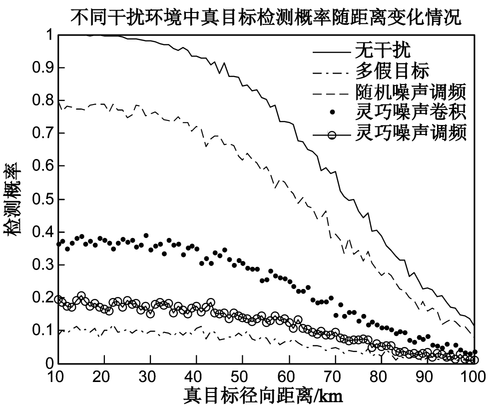


图15 真目标检测概率

14

ISNPRJ

120m

3

. 15

ISNPRJ

.

χ_m R_t

χ_m

.

.

5 结论

DRFM

.

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DRFM

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