
Esempi/ esercitazioni: Ricerca Short

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Radar di ricerca (Short range)

Si dimensioni un radar di ricerca con le seguenti caratteristiche:

Banda S: 3 GHz

Portata: 120 Km

Velocità massima ± 300 m/s

Risoluzione in azimuth: 2°

Rotazione antenna: 5 giri/minuto

$P_{fa} = 10^{-6}$

$P_d = 0,9$ per bersaglio fisso con RCS = 1 m^2

Potenza di picco TX: $P_p = 5 \text{ KW}$

Figura di rumore: $F = 3 \text{ dB}$

Risoluzione in distanza 200 m

Dinamica lineare istantanea 40 dB

$L =$ perdite totali = 8 dB

Sistemi Radar

Radar di ricerca (short range)

Banda L: 3 GHz

Portata: 120 Km

Velocità massima ± 300 m/s

Max Range: $2R/c = 2 \cdot 120 \cdot 10^3 / 3 \cdot 10^8 = 0,8 \cdot 10^{-3}$ s

Max Doppler: $2V/\lambda = 2V f/c = 2 \cdot 300 \cdot 3 \cdot 10^9 / 3 \cdot 10^8 = 9600 = 9,6$ KHz

Range-Doppler Area of interest $= 2 \cdot 9600 \cdot 4/5 \cdot 10^{-3} \cong 15$

Per non avere ambiguità in range $PRF < c/(2R) = 1/(4/5 \cdot 10^{-3} \text{ s}) = 1,25$ KHz

Uso PRF stagger con 4 valori di PRF

Radar di ricerca (short range)

Risoluzione in azimuth: 2°

Rotazione antenna: 5 giri/minuto

Apertura del fascio: 2°

Dimensione antenna azimuth: $L = \lambda / (2/180 * \pi) = 0,1 / \pi * 90 = 9 / \pi \cong 3 \text{ m}$

time-on-target = $2^\circ / (5 * 360 / 60) = 2^\circ / (5 * 6) = 2/30 = 1/15 = 0,0667 \text{ s} = 66,7 \text{ ms}$

N° Impulsi nel time-on-target = $1/15 * \text{PRF} = 1/15 * 1,25 \cdot 10^3 = 1250/15 = 83,3$

In ogni batch: $83/4 \cong 21$ impulsi

Da batch a batch cambio non solo PRF, ma anche frequenza

Radar di ricerca (short range)

$$P_{fa} = 10^{-6}$$

$$P_d = 0,9 \text{ per bersaglio fisso con RCS} = 1 \text{ m}^2$$

Bersaglio fisso \rightarrow serve SNR=13 dB

Assumendo di guadagnare un fattore 20 sul rumore termico per integrazione coerente (13 dB)

-Basta su singolo impulso un SNR= 0 dB

(considerando un guadagno di integrazione non coerente fra batch di 3 dB)

Possiamo pensare che bastino -3 dB.

Radar di ricerca (short range)

Potenza di picco TX: $P_p = 5 \text{ KW}$

Figura di rumore: $F = 3 \text{ dB}$

$$SNR = \frac{P_p G A_e \sigma_{av}}{(4\pi)^2 R^4 L kT_0 F B} B \tau_p$$

$$A_e = 0,5 * 3 * 2 \text{ m}^2 = 3 \text{ m}^2 \rightarrow 5 \text{ dB}$$

$$G = 4\pi * A_e / \lambda^2 = 4\pi * 3 / (0,1)^2 \rightarrow 11 + 5 - 2 * (-10) \text{ dB} \\ = 16 + 20 = 36$$

$$R = 120 \text{ Km} \rightarrow 51 \text{ dB}$$

$$\tau_p|_{\text{dB}} = -45 - 3 = -48 \quad \text{scegliamo} \rightarrow 20 * 10^{-6} \text{ s} = 20 \mu\text{s}$$

	dB+	dB-
P_p	37	
G	36	
A_e	5	
σ	0	
τ_p		
$(4\pi)^2$		22
R^4		204
F		3
kT_0		-204
L		8
	$78 + \tau_p _{\text{dB}}$	33
	$45 + \tau_p _{\text{dB}}$	
SNR	-3	

Radar di ricerca (short range)

Risoluzione in distanza 200 m

Dinamica lineare istantanea 40 dB

$$SNR = \frac{P_p G A_e \sigma_{av}}{(4\pi)^2 R^4 L k T_0 F B} B \tau_p$$

Risoluzione 200 m = $k \cdot c / (2B) = 1,4 \cdot 3 \cdot 10^8 / (2 B)$

$k = 1,4$ per Hamming

$B = 2,1 \cdot 10^8 / 200 = 10^6 = 1 \text{ MHz}$

$B \tau_p = 1 \text{ MHz} \cdot 20 \mu\text{s} = 20$ Forma d'onda "difficile" in termini di dinamica

Barker insufficiente,

Chirp ha lobi di Fresnel a $S.L.F. \Big|_{dB} = 20 \log(BT) + 3 = 26 + 3 = 29 \text{ dB}$

Frank ha lobi : $PSR = \pi \sqrt{N} = \pi M \Rightarrow 9,94 + 10 \cdot \log_{10}(N) \quad N = 1024 = (32)^2$

Sistemi Radar

Radar di ricerca (short range)

Riflettività del clutter: -27 dB

Cella di clutter

$$\text{cella di clutter} = \frac{\tau_C}{2 \sin \theta} \theta_{AZ} R$$

Cella di clutter corretta

$$\text{cella di clutter corretta} = \frac{\tau_C}{2\sqrt{2} \sin \theta} \theta_{AZ} R$$

$$CNR = \frac{P_p G A_e \sigma_0}{(4\pi)^2 R^4 L k T_0 F B} B \tau_P \frac{c \tau_C}{2\sqrt{2}} \theta_{AZ} R$$

Radar di ricerca (short range)

Riflettività del clutter: -27 dB

$$SNR = \frac{P_p G A_e \sigma_{av}}{(4\pi)^2 R^4 L k T_0 FB} B \tau_p$$

$$CNR = \frac{P_p G A_e \sigma_0}{(4\pi)^2 R^4 L k T_0 FB} B \tau_p \frac{c \tau_c}{2\sqrt{2}} \theta_{AZ} R$$

$$SCR = \frac{\sigma_{av}}{\sigma_0 \frac{c \tau_c}{2\sqrt{2}} \theta_{AZ} R} = \frac{\sigma_{av}}{\sigma_0 \left(\frac{c \tau_c}{2} \right) \theta_{AZ} R} \sqrt{2}$$

$$\theta_{AZ} = (2/180 * \pi) = \pi/90 = 5-20 = -15$$

$$R = 50 \text{ Km} \quad 47 \text{ dB}$$

SCR	dB+	dB-
σ	0	
σ_0		-27
$c\tau_c/2$		23
θ_{AZ}		-15
R		47
$\sqrt{2}$	1,5	
	1,5	28
SCR	-26,5 dB	

Radar di ricerca (short range)

Spettro di clutter gaussiano

dev standard dello spettro di velocità $\sigma_v=0.2$ m/s

$$S(f) = P_c \frac{1}{\sqrt{2\pi\sigma_f}} e^{-\frac{f^2}{2\sigma_f^2}} \quad R(t) = P_c e^{-2\pi^2\sigma_f^2 t^2}$$

$$R(K) = R(kPRT) = R(k / PRF) = P_c e^{-2\pi^2\left(\frac{\sigma_f}{PRF}\right)^2 k^2} = P_c \rho^{k^2}$$

$$\rho = e^{-2\pi^2\left(\frac{\sigma_f}{PRF}\right)^2} \quad \sigma_f = 2 \sigma_v / \lambda = 2 * 0.2 / 0.1 = 4 \text{ Hz}$$

$$\rho = \exp\left[-2\left(\pi\frac{\sigma_f}{PRF}\right)^2\right] = \exp\left[-2\left(\pi\frac{4}{1.25 \cdot 10^3}\right)^2\right] = \exp\left[-2\left(\frac{10}{10^3}\right)^2\right] = \exp[-2 \cdot 10^{-4}] = 0.9998$$

$$\rho^4 = \exp\left[-8\left(\pi\frac{\sigma_f}{PRF}\right)^2\right] = \exp[-8 \cdot 10^{-4}] = 0.9992 \quad \rho^9 = \exp\left[-18\left(\pi\frac{\sigma_f}{PRF}\right)^2\right] = \exp[-18 \cdot 10^{-4}] = 0.9982$$

Sistemi Radar

Radar di ricerca (short range)

Spettro di clutter gaussiano

dev standard dello spettro di velocità $\sigma_v=0.2$ m/s

Con singolo cancellatore:

$$\begin{aligned} IF(f_d) &= \frac{|\sin(\pi f_d T)|^2 \int_{-\infty}^{\infty} S_i(f) df}{\int_{-\infty}^{\infty} \sin^2(\pi f T) S_i(f) df} = \frac{2 |\sin(\pi f_d T)|^2 \int_{-\infty}^{\infty} S_i(f) df}{\int_{-\infty}^{\infty} [1 - \cos(2\pi f T)] S_i(f) df} = \\ &= \frac{2 \sin^2(\pi f_d T)}{1 - \text{Re}\{\rho_i(T)\}} = \frac{2 \sin^2(\pi f_d T)}{2 \cdot 10^{-4}} = 10^4 \sin^2(\pi f_d T) \quad \rho = 0.9998 \end{aligned}$$

Alla Doppler part a PRF/2 : $IF(f_d) = 10^4 \sin^2(\pi/2) \Leftrightarrow 40\text{dB}$

$$\text{SCR}_{\text{out}} = -26,5 \text{ dB} + 40 \text{ dB} = 13,5 \text{ dB}$$

Radar di ricerca (short range)

Potenza di picco TX: $P_p = 5 \text{ KW}$

Figura di rumore: $F = 3 \text{ dB}$

$$SNR = \frac{P_p G A_e \sigma_{av}}{(4\pi)^2 R^4 L kT_0 F B} B \tau_p$$

$A_e = 5 \text{ dB}$

$G = 36 \text{ dB}$

$R = 50 \text{ Km} \rightarrow 47 \text{ dB}$

$\tau_p |_{\text{dB}} = 20 \mu\text{s} \rightarrow 13 - 60 = -47 \text{ dB}$

$$SCNR = \frac{S}{C+N} = \frac{1}{1/SCR + 1/SNR} = \rightarrow 13,3 \text{ dB}$$

	dB+	dB-
P_p	37	
G	36	
A_e	5	
σ	0	
τ_p	-47	
$(4\pi)^2$		22
R^4		188
F		3
kT_0		-204
L		8
	31	17
SNR	14	
SNR	14+13=27	

Radar di ricerca (short range)

Spettro di clutter gaussiano

dev standard dello spettro di velocità $\sigma_v=0.2$ m/s

Con singolo cancellatore, a Doppler pari a PRF/20:

$$IF(f_d) = 10^4 \sin^2(\pi f_d T) = 10^4 \sin^2(\pi/20) = 10^4 (0,1564)^2 = 10^4 0,02447 = 40 - 16 = 24$$

$$\text{SCR}_{\text{out}} = -26,5 \text{ dB} + 24 \text{ dB} = -2,5 \text{ dB}$$

Radar di ricerca (short range)

Con cancellatore binomiale:

$$H(f) = \left(1 - e^{j2\pi f / PRF}\right)^M = \sum_{n=0}^M \binom{M}{n} (-1)^n e^{j2\pi n f / PRF}$$

$$|H(f)|^2 = \left|1 - e^{j2\pi f / PRF}\right|^{2M} = \sum_{n=0}^M \sum_{k=0}^M \binom{M}{n} \binom{M}{k} (-1)^{n+k} e^{j2\pi(n-k) f / PRF}$$

$$|H(f)|^2 = [2 - 2\cos(2\pi f / PRF)]^M = 4^M \sin^{2M}(\pi f / PRF) =$$

$$= \frac{4^M}{(2j)^{2M}} \left[e^{j\pi f / PRF} - e^{-j\pi f / PRF} \right]^{2M} = (-1)^{-M} \sum_{n=0}^{2M} \binom{2M}{n} e^{j\pi n f / PRF} (-1)^{(2M-n)} e^{-j\pi(2M-n) f / PRF} =$$

$$= \sum_{n=0}^{2M} \binom{2M}{n} e^{-j2\pi(M-n) f / PRF} (-1)^{M-n} = \sum_{n=0}^{M-1} \binom{2M}{n} e^{-j2\pi(M-n) f / PRF} (-1)^{M-n} + \binom{2M}{M} + \sum_{n=M+1}^{2M} \binom{2M}{n} e^{-j2\pi(M-n) f / PRF} (-1)^{M-n} =$$

$$= \sum_{n=0}^{M-1} \binom{2M}{n} e^{-j2\pi(M-n) f / PRF} (-1)^{M-n} + \binom{2M}{M} + \binom{2M}{M} + \sum_{k=0}^{M-1} \binom{2M}{2M-k} e^{j2\pi(M-k) f / PRF} (-1)^{M-k} =$$

$$= \binom{2M}{M} + \sum_{n=0}^{M-1} \binom{2M}{n} (-1)^{M-n} \left[e^{-j2\pi(M-n) f / PRF} + e^{j2\pi(M-n) f / PRF} \right] = \binom{2M}{M} + 2 \sum_{n=0}^{M-1} \binom{2M}{n} (-1)^{M-n} \cos[2\pi(M-n) f / PRF]$$

$$k = 2M - n \quad 2M - (M + 1) = M - 1 \quad (M - n) = M - (2M - k) = -(M - k)$$

Sistemi Radar

Radar di ricerca (short range)

Con cancellatore binomiale:

$$\begin{aligned}
 & \int_{-\infty}^{\infty} |H(f)|^2 S_i(f) df = \\
 & \int_{-\infty}^{\infty} \binom{2M}{M} S_i(f) df + \int_{-\infty}^{\infty} \sum_{n=0}^{M-1} \binom{2M}{n} (-1)^{M-n} \left[e^{-j2\pi(M-n)f/PRF} + e^{j2\pi(M-n)f/PRF} \right] S_i(f) df = \\
 & = \binom{2M}{M} P_C + \sum_{n=0}^{M-1} \binom{2M}{n} (-1)^{M-n} \int_{-\infty}^{\infty} \left[e^{-j2\pi(M-n)f/PRF} + e^{j2\pi(M-n)f/PRF} \right] S_i(f) df = \\
 & = \binom{2M}{M} P_C + P_C \sum_{n=0}^{M-1} \binom{2M}{n} (-1)^{M-n} \left[\rho[-(M-n)/PRF] + \rho[(M-n)/PRF] \right] = \\
 & = \binom{2M}{M} P_C + 2P_C \sum_{n=0}^{M-1} \binom{2M}{n} (-1)^{M-n} \operatorname{Re}\{\rho[(M-n)/PRF]\} = \\
 & = \binom{2M}{M} P_C + 2P_C \sum_{m=1}^M \binom{2M}{M-m} (-1)^m \operatorname{Re}\{\rho[m/PRF]\}
 \end{aligned}$$

$$m = M - n \quad n = M - m \quad n = 0 \quad m = M \quad n = M - 1 \quad m = 1$$

Radar di ricerca (short range)

Con cancellatore binomiale:

$$\int_{-\infty}^{\infty} |H(f)|^2 S_i(f) df = \binom{2M}{M} P_C + 2P_C \sum_{m=1}^M \binom{2M}{M-m} (-1)^m \operatorname{Re} \{ \rho[m / PRF] \}$$

$$M = 1$$

$$\rightarrow 2P_C + 2P_C \sum_{m=1}^1 \binom{2}{1-m} (-1)^m \operatorname{Re} \{ \rho[m / PRF] \} = 2P_C [1 - \operatorname{Re} \{ \rho[PRT] \}]$$

$$M = 2$$

$$\rightarrow \binom{4}{2} P_C + 2P_C \sum_{m=1}^2 \binom{4}{2-m} (-1)^m \operatorname{Re} \{ \rho[m / PRF] \} = 6 - 8 \operatorname{Re} \{ \rho[PRT] \} + 2 \operatorname{Re} \{ \rho[2 PRT] \}$$

$$M = 3$$

$$\begin{aligned} &\rightarrow \binom{6}{3} P_C + 2P_C \sum_{m=1}^3 \binom{6}{3-m} (-1)^m \operatorname{Re} \{ \rho[m / PRF] \} = \\ &= P_C \left[\binom{6}{3} - 2 \binom{6}{2} \operatorname{Re} \{ \rho[PRT] \} + 2 \binom{6}{1} \operatorname{Re} \{ \rho[2 PRT] \} - 2 \binom{6}{0} \operatorname{Re} \{ \rho[3 PRT] \} \right] = \\ &= P_C [20 - 30 \operatorname{Re} \{ \rho[PRT] \} + 12 \operatorname{Re} \{ \rho[2 PRT] \} - 2 \operatorname{Re} \{ \rho[3 PRT] \}] \end{aligned}$$

Sistemi Radar

Radar di ricerca (short range)

Con cancellatore binomiale:

$$IF(f_d) = \frac{|H(f)|^2 \int_{-\infty}^{\infty} S_i(f) df}{\int_{-\infty}^{\infty} |H(f)|^2 S_i(f) df} = \frac{4^M \sin^{2M}(\pi f_d T) P_c}{\binom{2M}{M} P_c + 2P_c \sum_{m=1}^M \binom{2M}{M-m} (-1)^m \operatorname{Re}\{\rho[m / PRF]\}} = \frac{4^M \sin^{2M}(\pi f_d T)}{\binom{2M}{M} + 2 \sum_{m=1}^M \binom{2M}{M-m} (-1)^m \operatorname{Re}\{\rho[m / PRF]\}}$$

$$M = 1$$

$$IF(f_d) = \frac{4 \sin^2(\pi f_d T)}{2[1 - \operatorname{Re}\{\rho[PRT]\}]}$$

$$M = 2$$

$$IF(f_d) = \frac{16 \sin^4(\pi f_d T)}{6 - 8 \operatorname{Re}\{\rho[PRT]\} + 2 \operatorname{Re}\{\rho[2PRT]\}}$$

$$M = 3$$

$$IF(f_d) = \frac{64 \sin^6(\pi f_d T)}{20 - 30 \operatorname{Re}\{\rho[PRT]\} + 12 \operatorname{Re}\{\rho[2PRT]\} - 2 \operatorname{Re}\{\rho[3PRT]\}}$$

Sistemi Radar

Radar di ricerca (short range)

Con cancellatore binomiale:

$$\rho = 0.9998 \quad \rho^4 = 0.9992 \quad \rho^9 = 0.9982$$

$$f_d T = 1/20 \rightarrow 10 \log_{10} \sin(\pi f_d T) = -8$$

$$M=1$$

$$IF(f_d) = \frac{4 \sin^2(\pi f_d T)}{2[1 - \text{Re}\{\rho^{PRT}\}]} = \frac{2 \sin^2(\pi f_d T)}{1 - 0.9998} = \frac{\sin^2(\pi f_d T)}{10^{-4}} \rightarrow 40 + 2 * 10 \log_{10}(\pi f_d T) \text{ dB}$$

$$f_d T = 1/2 \quad IF = 40 \text{ dB} \quad f_d T = 1/20 \quad IF = 24 \text{ dB}$$

$$M=2$$

$$IF(f_d) = \frac{16 \sin^4(\pi f_d T)}{6 - 8 \text{Re}\{\rho^{PRT}\} + 2 \text{Re}\{\rho^{2PRT}\}} = \frac{8 \sin^4(\pi f_d T)}{3 - 4 * 0.9998 + 0.9992} = \frac{\sin^4(\pi f_d T)}{3 \cdot 10^{-8}} \rightarrow 75 + 4 * 10 \log_{10}(\pi f_d T) \text{ dB}$$

$$f_d T = 1/2 \quad IF = 75 \text{ dB} \quad f_d T = 1/20 \quad IF = 43 \text{ dB}$$

$$M=3$$

$$IF(f_d) = \frac{64 \sin^6(\pi f_d T)}{20 - 30 \text{Re}\{\rho^{PRT}\} + 12 \text{Re}\{\rho^{2PRT}\} - 2 \text{Re}\{\rho^{3PRT}\}} = \frac{\sin^6(\pi f_d T)}{1.5 \cdot 10^{-11}} \rightarrow 108.5 + 6 * 10 \log_{10}(\pi f_d T)$$

$$f_d T = 1/2 \quad IF = 108.5 \text{ dB} \quad f_d T = 1/20 \quad IF = 60.5 \text{ dB}$$

Sistemi Radar

Radar di ricerca (short range)

Con cancellatore binomiale:

$$|H(f)|^2 = \binom{2M}{M} + 2 \sum_{n=0}^{M-1} \binom{2M}{n} (-1)^{M-n} \cos[2\pi(M-n) f / PRF]$$

$$\frac{1}{PRF} \int_{-PRF/2}^{PRF/2} |H(f)|^2 df = \frac{1}{PRF} \int_{-PRF/2}^{PRF/2} \binom{2M}{M} df + \frac{1}{PRF} \int_{-PRF/2}^{PRF/2} 2 \sum_{n=0}^{M-1} \binom{2M}{n} (-1)^{M-n} \cos[2\pi(M-n) f / PRF] df = \binom{2M}{M} = \frac{(2M)!}{(M!)^2}$$

$$M = 1 \quad \rightarrow \frac{(2M)!}{(M!)^2} = 2$$

$$M = 2 \quad \rightarrow \frac{(2M)!}{(M!)^2} = 4 * 3 / 2 = 6$$

$$M = 3 \quad \rightarrow \frac{(2M)!}{(M!)^2} = 6 * 5 * 4 / (3 * 2) = 20$$

Radar di ricerca (short range)

Con cancellatore binomiale:

$$IF_{-medio} = \frac{\frac{1}{PRF} \int_{-PRF/2}^{PRF/2} |H(f)|^2 df \int_{-\infty}^{\infty} S_i(f) df}{\int_{-\infty}^{\infty} |H(f)|^2 S_i(f) df} = \frac{\binom{2M}{M}}{\binom{2M}{M} + 2 \sum_{m=1}^M \binom{2M}{M-m} (-1)^m \operatorname{Re}\{\rho[m/PRF]\}} = \frac{1}{1 + 2 \sum_{m=1}^M \frac{(-1)^m (M!)^2}{(M-m)!(M+m)!} \operatorname{Re}\{\rho[m/PRF]\}}$$

$$\binom{2M}{M-m} / \binom{2M}{M} = \frac{(2M)!}{(M-m)!(M+m)!} \frac{(M!)^2}{(2M)!} = \frac{(M!)^2}{(M-m)!(M+m)!}$$

$$M = 1$$

$$IF_{-medio} = \frac{2}{2[1 - \operatorname{Re}\{\rho[PRT]\}]} = \frac{1}{1 - \operatorname{Re}\{\rho[PRT]\}} = \frac{1}{2 \cdot 10^{-4}} \rightarrow 37 \text{ dB}$$

$$M = 2$$

$$IF_{-medio} = \frac{6}{6 - 8 \operatorname{Re}\{\rho[PRT]\} + 2 \operatorname{Re}\{\rho[2PRT]\}} = \frac{1}{1 - 4/3 \operatorname{Re}\{\rho[PRT]\} + 1/3 \operatorname{Re}\{\rho[2PRT]\}} = \frac{1}{8 \cdot 10^{-8}} \rightarrow 71 \text{ dB}$$

$$M = 3$$

$$IF_{-medio} = \frac{20}{20 - 30 \operatorname{Re}\{\rho[PRT]\} + 12 \operatorname{Re}\{\rho[2PRT]\} - 2 \operatorname{Re}\{\rho[3PRT]\}} = \frac{1}{1 - 3/2 \operatorname{Re}\{\rho[PRT]\} + 3/5 \operatorname{Re}\{\rho[2PRT]\} - 1/10 \operatorname{Re}\{\rho[3PRT]\}} = \frac{1}{4,8 \cdot 10^{-11}} \rightarrow 103 \text{ dB}$$

Radar di ricerca (short range)

Effetto rotazione antenna:

$$\sigma_f = \frac{2}{\lambda} \sigma'_v$$

$$\sigma'_v = \sqrt{\sigma_v^2 + \sigma_A^2}$$

$$\sigma_A = 0.13 \frac{\lambda PRF}{N} = 0.13 \frac{\lambda}{ToT} = 0.13 \lambda \frac{\omega_a}{\theta_0}$$

$$\sigma_A = 0.13 \frac{\lambda}{ToT} = 0.13 \frac{0.1}{66.7 \cdot 10^{-3}} = \frac{13}{66.7} = 0.195$$

$$\sigma'_v = \sqrt{\sigma_v^2 + \sigma_A^2} = 0.27925$$

$$\sigma_f = \frac{2}{\lambda} \sigma'_v = 5.585 \text{ Hz}$$

$$\rho = \exp\left[-2 \left(\pi \frac{\sigma_f}{PRF}\right)^2\right] = \exp\left[-2 \left(\pi \frac{5.584}{1.25 \cdot 10^3}\right)^2\right] = 0.9996$$

Radar di ricerca (short range)

Con cancellatore binomiale:

$$\rho = 0.999 \quad \rho^4 = 0.996 \quad \rho^9 = 0.991$$

$$f_d T = 1/20 \rightarrow 10 \log_{10} \sin(\pi f_d T) = -8$$

$M=1$

$$IF(f_d) = \frac{4 \sin^2(\pi f_d T)}{2[1 - \text{Re}\{\rho[PRT]\}]} = \frac{2 \sin^2(\pi f_d T)}{1 - 0.999} = \frac{2 \sin^2(\pi f_d T)}{10^{-3}} \rightarrow 33 + 2 * 10 \log_{10}(\pi f_d T) \text{ dB}$$

$$f_d T = 1/2 \quad IF = 33 \text{ dB} \quad f_d T = 1/20 \quad IF = 17 \text{ dB}$$

$M=2$

$$IF(f_d) = \frac{16 \sin^4(\pi f_d T)}{6 - 8 \text{Re}\{\rho[PRT]\} + 2 \text{Re}\{\rho[2PRT]\}} = \frac{8 \sin^4(\pi f_d T)}{3 - 4 * 0.999 + 0.996} = \frac{8 \sin^4(\pi f_d T)}{10^{-7}} \rightarrow 61 + 4 * 10 \log_{10}(\pi f_d T) \text{ dB}$$

$$f_d T = 1/2 \quad IF = 61 \text{ dB} \quad f_d T = 1/20 \quad IF = 29 \text{ dB}$$

$M=3$

$$IF(f_d) = \frac{64 \sin^6(\pi f_d T)}{20 - 30 \text{Re}\{\rho[PRT]\} + 12 \text{Re}\{\rho[2PRT]\} - 2 \text{Re}\{\rho[3PRT]\}} \rightarrow 87.5 + 6 * 10 \log_{10}(\pi f_d T)$$

$$f_d T = 1/2 \quad IF = 87.5 \text{ dB} \quad f_d T = 1/20 \quad IF = 39.5 \text{ dB}$$

Sistemi Radar

Radare di ricerca (short range)

Spettro di clutter gaussiano largo

Con triplo cancellatore:

A Doppler pari a PRF/2:

$$\text{SCR}_{\text{out}} = -26,5 \text{ dB} + 87,5 \text{ dB} = 61 \text{ dB}$$

A Doppler pari a PRF/20:

$$\text{SCR}_{\text{out}} = -26,5 \text{ dB} + 39,5 \text{ dB} = 13 \text{ dB}$$