

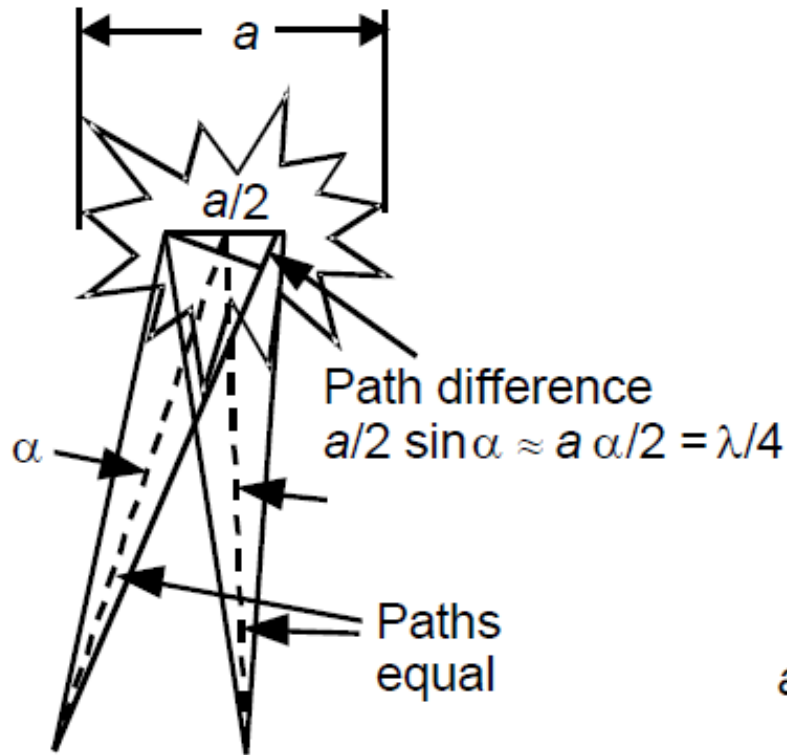
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# **Prestazioni di rivelazione su impulso singolo Target fluttuante**

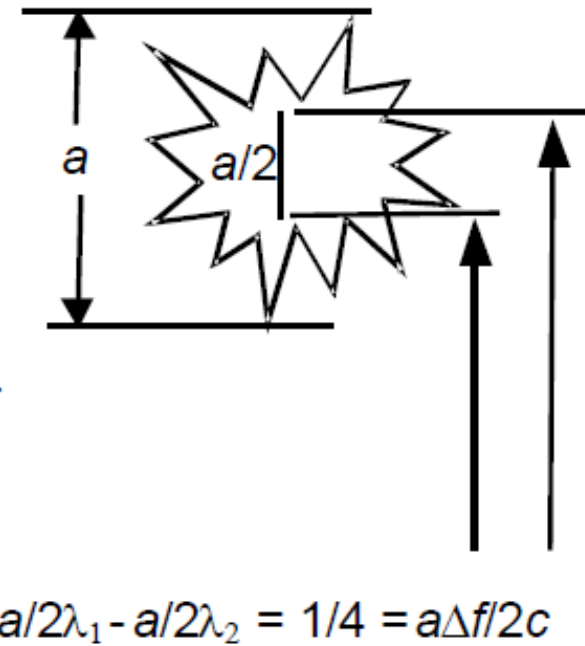
# Bersagli fluttuanti (I)

- RCS Is the Ratio of Power Density Scattered by the Target in the Direction of the Radar, to the Power Density Incident on the Target
- RCS Generally Related To Target Size, but
  - Flat or Cylindrical Surfaces Produce Large Specular Returns
  - Corner Reflectors Produce Large Monostatic RCS
  - Stealth Techniques (Shaping, RAM, and Non-metallic Materials Can Reduce RCS)
- RCS of Large Complex Objects With Dimension  $a$  Can
  - Vary With Viewing Aspect (LOS)  $\geq \lambda / 2a$
  - Vary With Radar Frequency Changes  $\geq c / 2a$
- RCS of Targets Smaller Than  $\lambda / \pi$ 
  - Does Not Vary With LOS or Frequency Changes
  - Is Said to Be in the Raleigh Region
  - Varies With  $\lambda^{-4}$

# Bersagli fluttuanti (II)



a. LOS rotation



b. Frequency change

# Bersagli fluttuanti (III)

## Requirements for RCS Decorrelation

| Parameter                 | Value                     |
|---------------------------|---------------------------|
| Target Dimension (a)      | 2 m                       |
| Radar Frequency           | 9.5 GHz (X Band)          |
| Wavelength ( $\lambda$ )  | 0.0316 m                  |
| LOS Rotation Required     | 8 mR ( $\approx 0.5$ deg) |
| Target Rotation Rate      | 5 deg/s                   |
| Decorrelation Time        | 100 ms                    |
| Frequency Change Required | 75 MHz                    |

## Rotating Radar Example

| Parameter               | Value  |
|-------------------------|--------|
| PRF                     | 200 Hz |
| Time Between Pulses     | 5 ms   |
| Antenna Rotation Period | 10 s   |
| Antenna Beamwidth       | 1 deg  |
| Time on Target          | 30 ms  |

- For Target in Pervious Example
  - LOS Rotation Provides Dwell-to-dwell RCS Decorrelation (Swerling 1 and 3)
  - Frequency Agility Needed to Provide Pulse-to-pulse RCS Decorrelation (Swerling 2 and 4)

# Rivelazione per Bersagli fluttuanti (I)

Probabilità di rivelazione “istantanea” dipende dal valore di RCS “ $\sigma=|a|^2$ ” che si sperimenta in quello specifico momento. E’ di fatto una probabilità condizionata al valore di “ $\sigma=|a|^2$ ”:

$$P_d(\sigma) = \text{Prob}\{z > T | \sigma; H_1\} = \int_{T/\sigma_d}^{\infty} 2t \exp\left\{-t^2 - \frac{\sigma \cdot |\chi(\tau, \nu)|^2}{\sigma_d^2}\right\} \cdot I_0\left[\frac{2t \sqrt{\sigma} \cdot |\chi(\tau, \nu)|}{\sigma_d}\right] dt$$

Probabilità di rivelazione globale si ottiene rimuovendo il condizionamento per saturazione tramite la DDP della variabile aleatoria  $\sigma$ :

$$P_d = \int_0^{\infty} P_d(\sigma) p_{\sigma}(\sigma) d\sigma$$

In generale risulta  $P_d \neq P_d(\sigma_{av})$

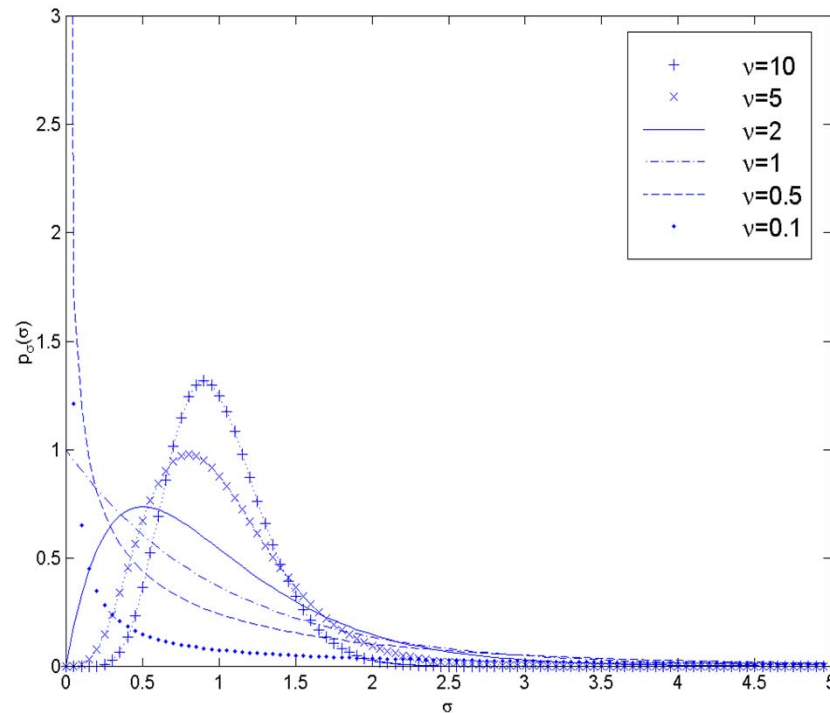
Solo se la DDP di  $\sigma$  è un Dirac (Bersaglio fisso) si ha:  $P_d = P_d(\sigma_{av})$

# Modello generale per la fluttuazione di RCS

Il modello di **RCS model** deve definire la DDP:

Un modello generale si ottiene usando la DDP gamma, con fattore di forma  $m$ :

$$p_{\sigma}(\sigma) = \frac{1}{(m-1)!} \left( \frac{m}{\sigma_{av}} \right)^m \sigma^{m-1} \exp \left[ -\frac{m}{\sigma_{av}} \sigma \right]$$



$m=1$  Swerling I-II

$m=2$  Swerling III-IV

$m \rightarrow \infty$  Swerling 0 (oppure 5)

$$\langle \sigma^n \rangle = \left( \frac{\sigma_{av}}{m} \right)^n \frac{(m+n-1)!}{(n-1)!}$$

$$\frac{\text{var } \sigma}{\sigma_{av}^2} = \frac{1}{m}$$

# Rivelazione per Bersagli fluttuanti (II)

$$P_d = \int_0^{\infty} P_d(\sigma) p_{\sigma}(\sigma) d\sigma = \int_0^{\infty} P_d(\sigma) \frac{1}{(m-1)! \left(\frac{m}{\sigma_{av}}\right)^m} \sigma^{m-1} \exp\left[-\frac{m}{\sigma_{av}} \sigma\right] d\sigma$$

$$P_d = \frac{e^{-\frac{T^2 / \sigma_d^2}{1+SNR/m}}}{(1+SNR/m)^{m-1}} \sum_{n=0}^{m-1} \binom{m-1}{n} \left(\frac{SNR}{m}\right)^n \sum_{k=0}^n \frac{1}{k!} \left(\frac{T^2 / \sigma_d^2}{1+SNR/m}\right)^k$$

$$m=1: \quad \text{Swerling I-II} \quad P_d = e^{-\frac{T^2}{\sigma_d^2 (1+SNR)}} = P_{fa}^{\frac{1}{1+SNR}}$$

$$m=2: \quad \text{Swerling III-IV} \quad P_d = e^{-\frac{T^2 / \sigma_d^2}{1+SNR/2}} \left[ 1 + \frac{T^2}{2\sigma_d^2} \frac{SNR}{(1+SNR/2)^2} \right]$$

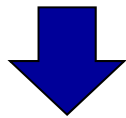
# Rivelazione per Bersagli fluttuanti (III)

*Via analitica semplice*

per  $m=1$ : Swerling I-II

$$z = |\tilde{z}| = |d_f(t) + a \cdot \chi(\tau, \nu)| > T$$

Se “ $a$ ” ha ampiezza Rayleigh e fase uniforme, è una v.a. gaussiana complessa con valor medio nullo e varianza  $\sigma_{av}$



Anche  $\tilde{z}$  è una v.a. gaussiana complessa con valor medio nullo, e varianza  $\sigma_{av} + \sigma_d^2$

Dunque “ $z$ ” ha DDP Rayleigh, come il solo disturbo in  $H_p H_0$

$$P_d = \text{Prob}\{z > T \mid H_1\} = \int_T^\infty p_z(z \mid H_1) dz = e^{-\frac{T^2}{\sigma_d^2 + \sigma_{av}}} = e^{-\frac{T^2}{\sigma_d^2 (1 + \sigma_{av}/\sigma_d^2)}} = e^{-\frac{T^2}{\sigma_d^2 (1 + SNR)}}$$

$$P_d = e^{-\frac{T^2}{\sigma_d^2 (1 + SNR)}} = P_{fa}^{1 + SNR}$$



# Rivelazione per Bersagli fluttuanti (III)

## Plots of S/N vs. PD and Swerling Type

