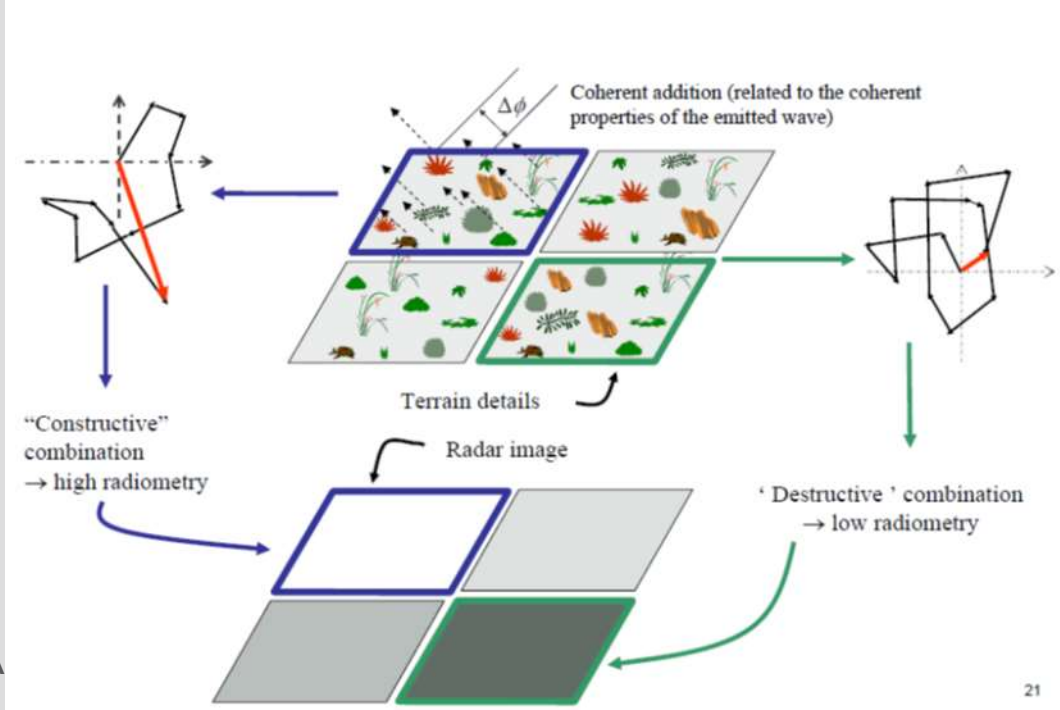
The physical origin of speckle

- Inherent to coherent systems (Amplitude and phase information)
- *Resolution cells are made up of many scatterers with different phases, leading to interference and the **noise-like** effect known as **speckle***
- **For each resolution cell, $\gamma\,(x, r)$ is equal to the sum of all scatterers contributions i. e.**

$$|u(x_o, r_o)| = |\,\gamma\,(x_o, r_o) \otimes u_o\,(x, r)\,| = |\,\underbrace{\Sigma\,\gamma_i\,(x_o, r_o)}_{\text{random sum}} \otimes u_o\,(x, r)\,|$$



Spekle corresponds to the "Salt&Pepper" effect of the image

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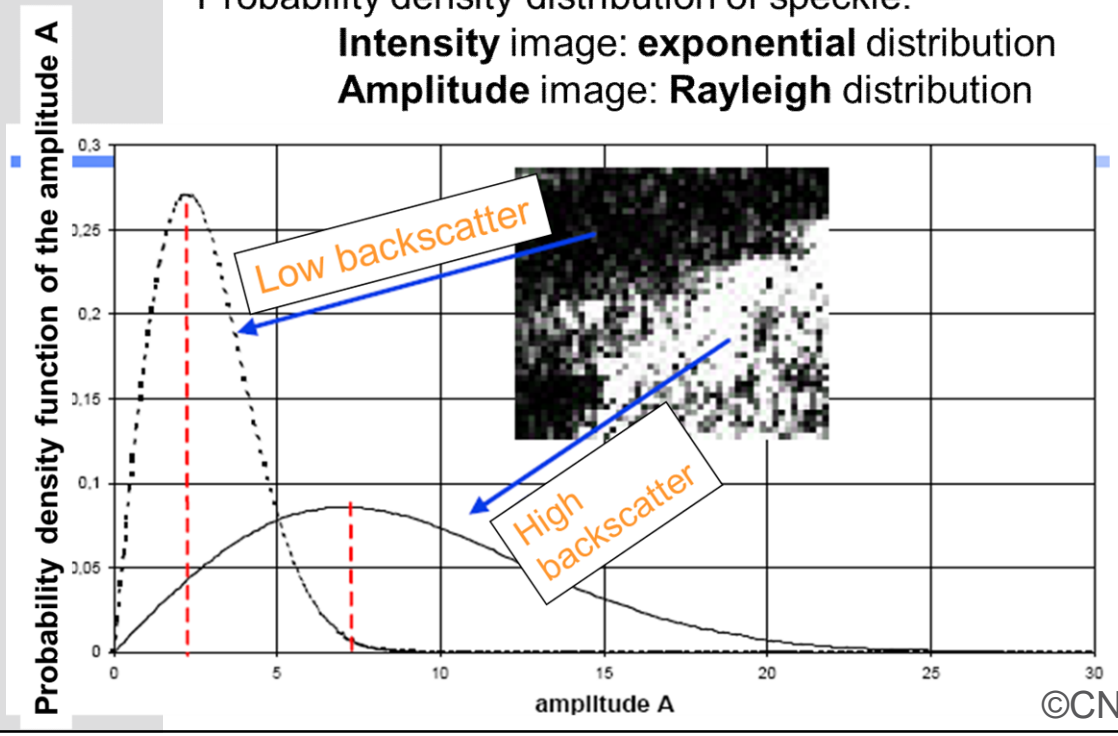
Statistics of speckle

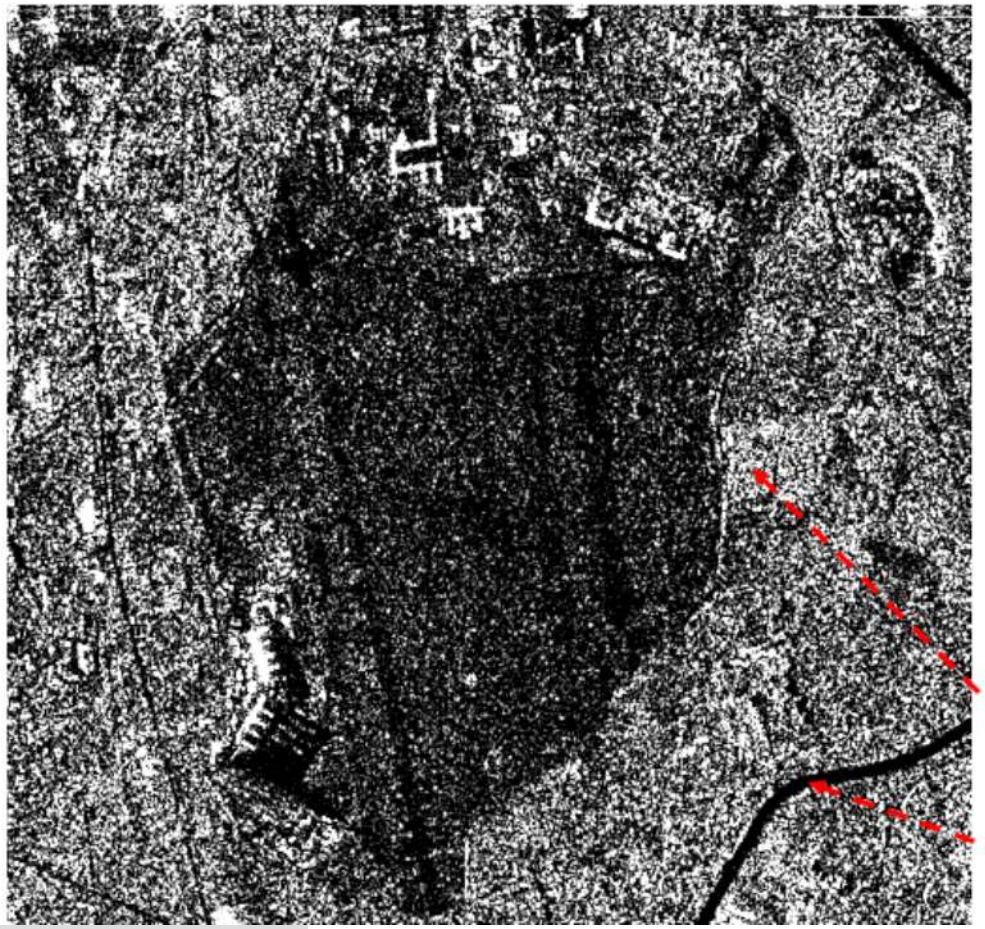
Speckle as inherent “noise-like” process:

- degrade image quality
- image interpretation more difficult
- Probability distribution function

Probability density distribution of speckle:
Intensity image: **exponential** distribution
Amplitude image: **Rayleigh** distribution



The speckle: a multiplicative noise



$$I = R \cdot v$$
$$E(v) = 1$$
$$\mathrm{var}(v) = 1/L$$

I : Measured intensity
R : Area reflectivity
(value to be estimated)
v : speckle noise
L : number of looks
(base image : L=1 look)

High reflectivity : high speckle

Low reflectivity : low speckle

Extract of RADARSAT image in fine mode / Salon de Provence

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Speckle and texture

◆ **Homogeneous areas :** Constant reflectivity and independence between speckle and underlying landscape:

$$I = R.v \longrightarrow E(R.v) = E(R) \cdot E(v) = E(R) = R$$

(It is possible to estimate I with 'massive averaging')

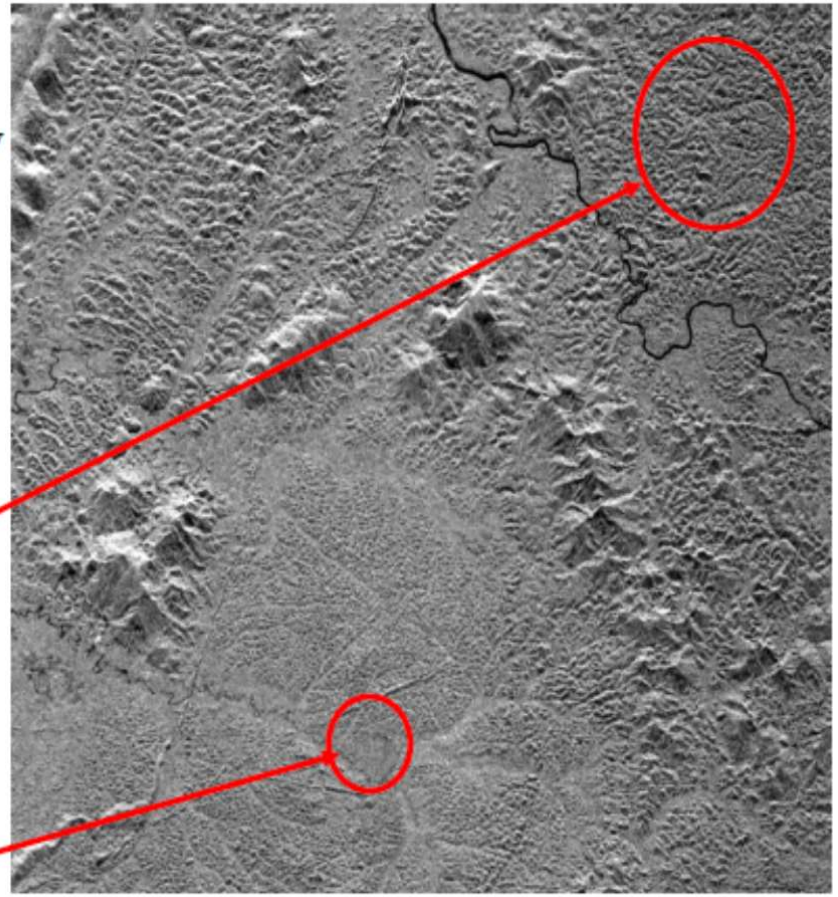
◆ **Zones with texture :** The speckle is not more the only source of radiometric variation of the image.

$$R = E(R) \cdot t \rightarrow I = E(R) \cdot t \cdot v \qquad (1)$$

v is the speckle and t the textural coefficient, such as :

$$E(t) = 1$$

• With respect to (1), intensity variations are attributed to a joint effect of speckle noise and of underlying texture.



Techniques to reduce the speckle

Optimize the information extraction process, i.e., the noise filtering process
…and improve the radar images **readability**

Single image

- **Multi-looking (spatial or spectral)**
- **Spatial adaptive filters** (Lee , Kuan, Frost, MAP etc.): *local estimations by sliding windows*

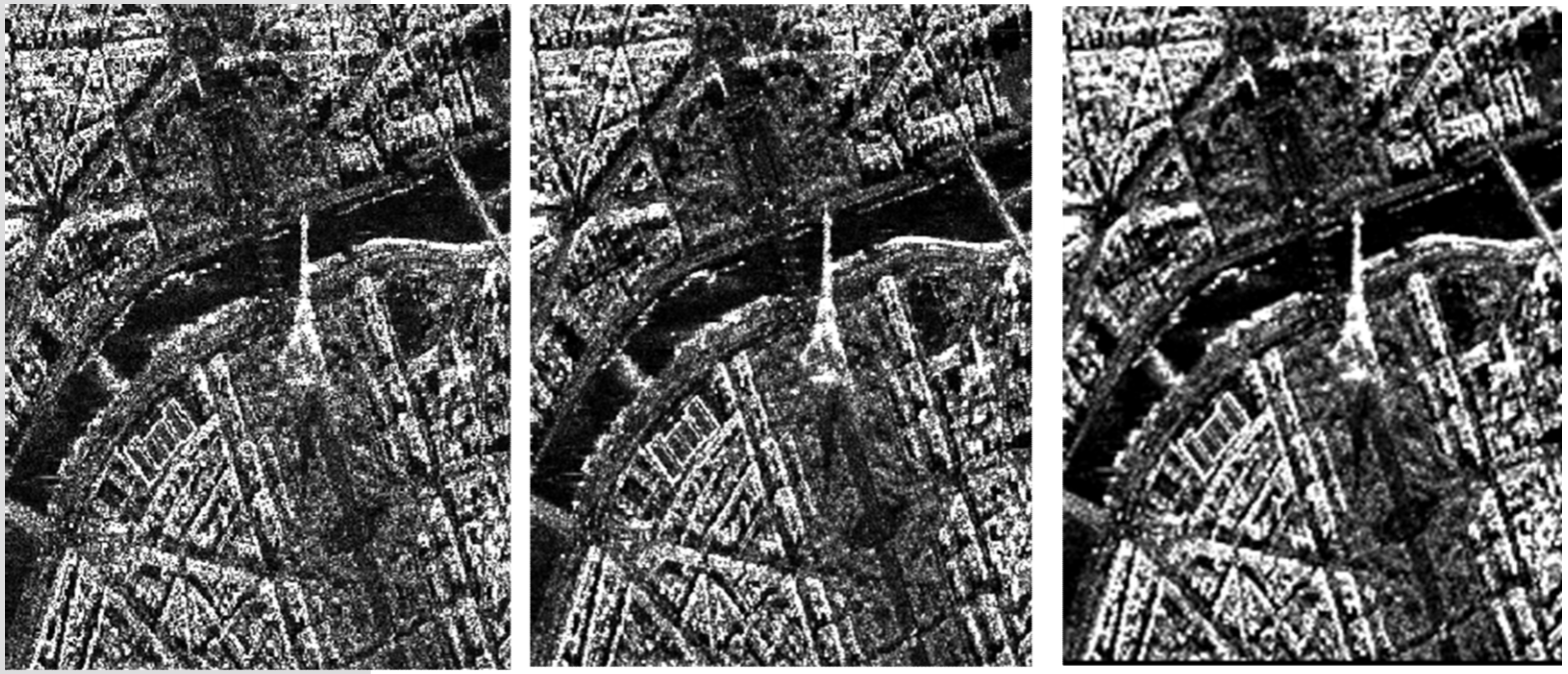
➡ Enhances radiometric resolution at the expense of spatial resolution.

Over a series of images (ex : multi-dates)

- Taking advantage of the speckle diversity in a series of images in order to decrease its level

Multi-looking technique

Multi-look technique: average of adjacent looks both in the spatial domain or in the spectral domain



A B C

A : Original one-look image
B : Multi-look image 2 x 2 (2 looks azimuts ; 2 looks distance)
C : Multi-look image 3 x 3 (3 looks azimuts ; 3 looks distance)