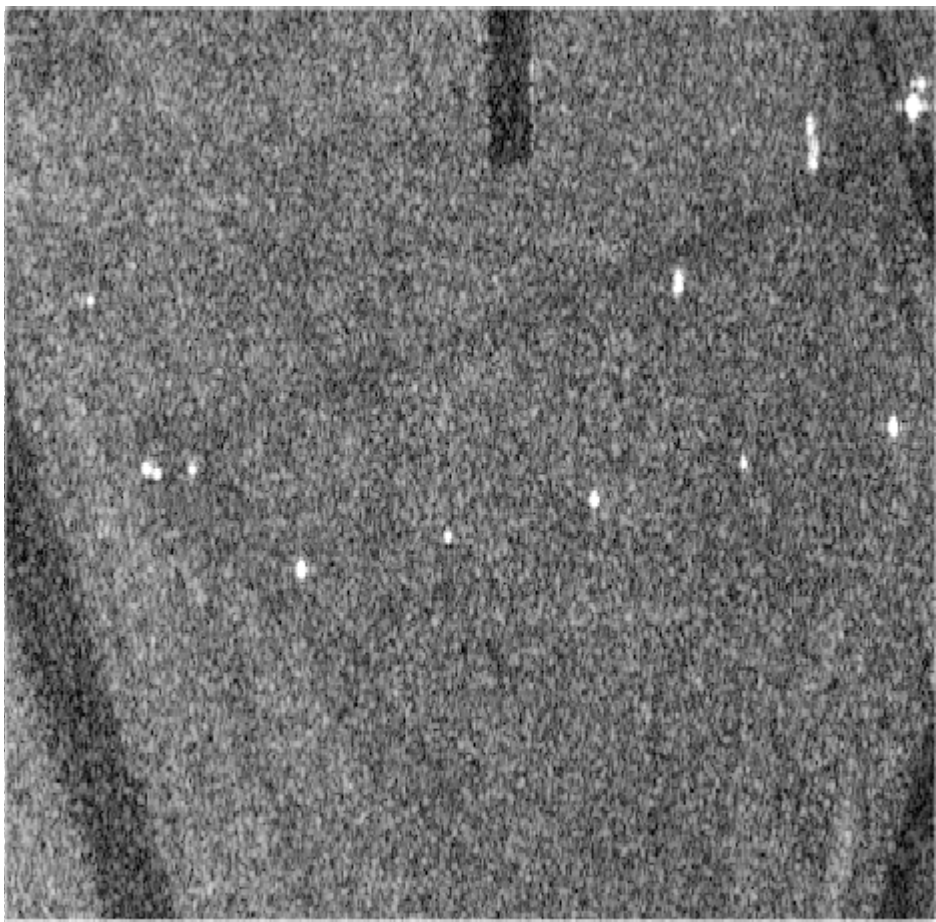


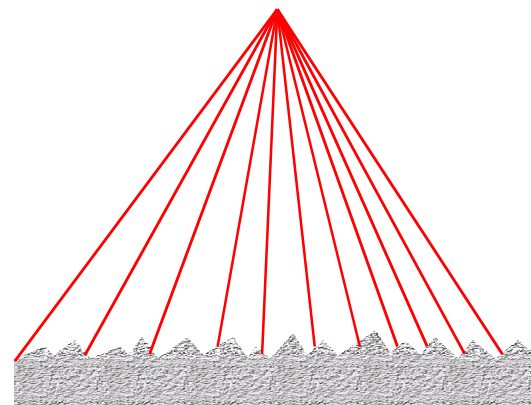
POLARIMETRIC SPECKLE FILTERING



SPECKLE PHENOMENON



OBSERVATION POINT



SURFACE ROUGHNESS
WAVELENGTH

SCATTERING FROM DISTRIBUTED
SCATTERERS



COHERENT INTERFERENCES OF WAVES
SCATTERED FROM MANY RANDOMLY
DISTRIBUTED ELEMENTARY SCATTERERS
INSIDE THE RESOLUTION CELL



GRANULAR NOISE

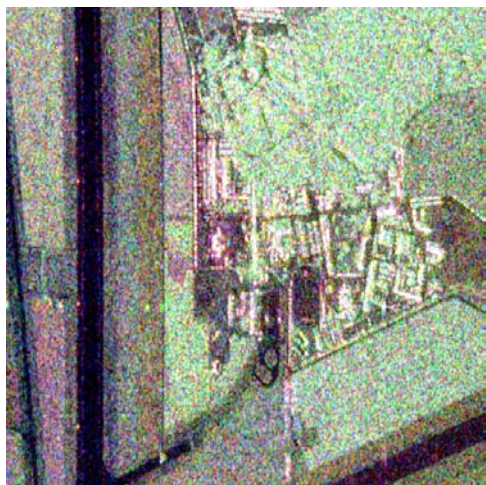


SPECKLE PHENOMENON

SPECKLE PHENOMENON



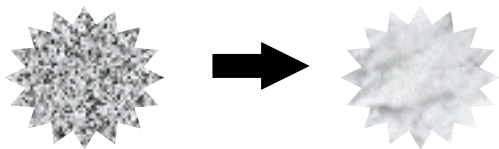
DISTORTION OF THE INTERPRETATION



SPECKLE FILTERING

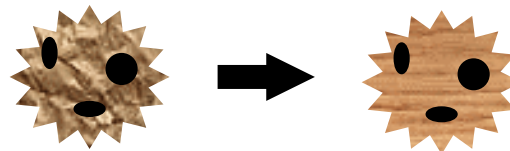


HOMOGENEOUS AREA



SPECKLE REDUCTION
(RADIOMETRIC RESOLUTION)

HETEROGENEOUS AREA



DETAILS PRESERVATION
(SPATIAL RESOLUTION)

SPECKLE REDUCTION

MULTI-LOOK SAR PROCESSING (BoxCar)

Averaging Amplitude / Intensity (Not complex images) of neighboring pixels

Good Noise Smoothing

Spatial Resolution Loss - blurring edges - erasing thin lines
Loss of linear or point features ...



LINEAR SPECKLE FILTERS

Median Filter

MAP Filter (Kuan)

Gradient Filter

Nagao Filter (Nagao)

Sigma Filter (Lee)

Frost Filter (Frost)

Geometrical Filter (Crimmins)

Morphological Filter (Safa, Flouzat)

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·
·
·

Local Statistics Filter (Lee 80)

SPECKLE : MULTIPLICATIVE NOISE MODEL

« **SPECKLE is a scattering phenomenon and not a noise.**
However, from the image SAR processing point of view, the speckle can be modeled as multiplicative noise for extended target » (Lee, IGARSS-98)

$$\underline{y} = \begin{bmatrix} y_{HH} \\ y_{HV} \\ y_{VV} \end{bmatrix} = \begin{bmatrix} n_{HH} & 0 & 0 \\ 0 & n_{HV} & 0 \\ 0 & 0 & n_{VV} \end{bmatrix} \begin{bmatrix} x_{HH} \\ x_{HV} \\ x_{VV} \end{bmatrix} = \begin{bmatrix} x_{HH} n_{HH} \\ x_{HV} n_{HV} \\ x_{VV} n_{VV} \end{bmatrix}$$

↑
SCATTERING
FIELD

↑
NOISE

↑
REFLECTIVITY
DENSITY

$$Y_{pqpq} = y_{pq} y_{pq}^* = X_{pqpq} v_{pqpq}$$

INTENSITY

$$A_{pqpq} = \sqrt{Y_{pqpq}} = \sqrt{y_{pq} y_{pq}^*}$$

AMPLITUDE

or: $\mu_v = E(v) = 1$

LOCAL STATISTICS LINEAR FILTER

$$\hat{X}_{i,j} = E(Y) + k(Y_{i,j} - E(Y))$$

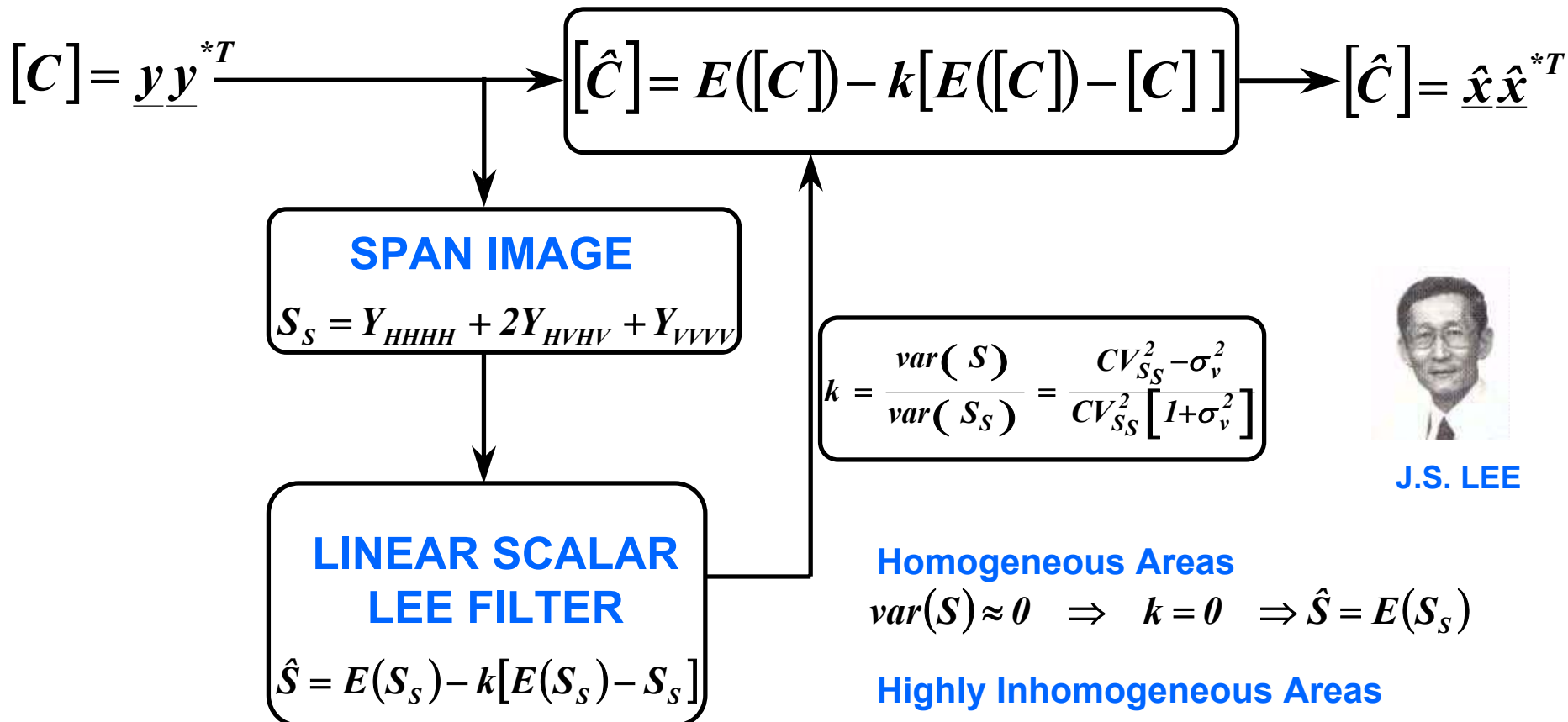
$$k = \frac{\text{var}(X)}{\text{var}(Y)} = \frac{CV_Y^2 - CV_v^2}{CV_Y^2 [1 + CV_v^2]} = \frac{\text{var}(Y) - E^2(Y)\sigma_v^2}{\text{var}(Y)[1 + \sigma_v^2]}$$

LOCAL STATISTICS $E^2(Y)$, $\text{var}(Y) = E(Y^2) - E^2(Y)$

A PRIORI INFORMATION $\sigma_v^2 = \text{var}(v) = CV_Y^2 = \frac{1}{N}$

IMAGE NUMBER OF LOOK

POLARIMETRIC VECTORIAL SPECKLE FILTER



J.S. LEE

Homogeneous Areas

$$\text{var}(S) \approx 0 \Rightarrow k = 0 \Rightarrow \hat{S} = E(S_S)$$

Highly Inhomogeneous Areas

$$\text{var}(S) \mapsto \text{var}(S_S) \Rightarrow k = 1 \Rightarrow \hat{S} = S_S$$

REFINED FILTER

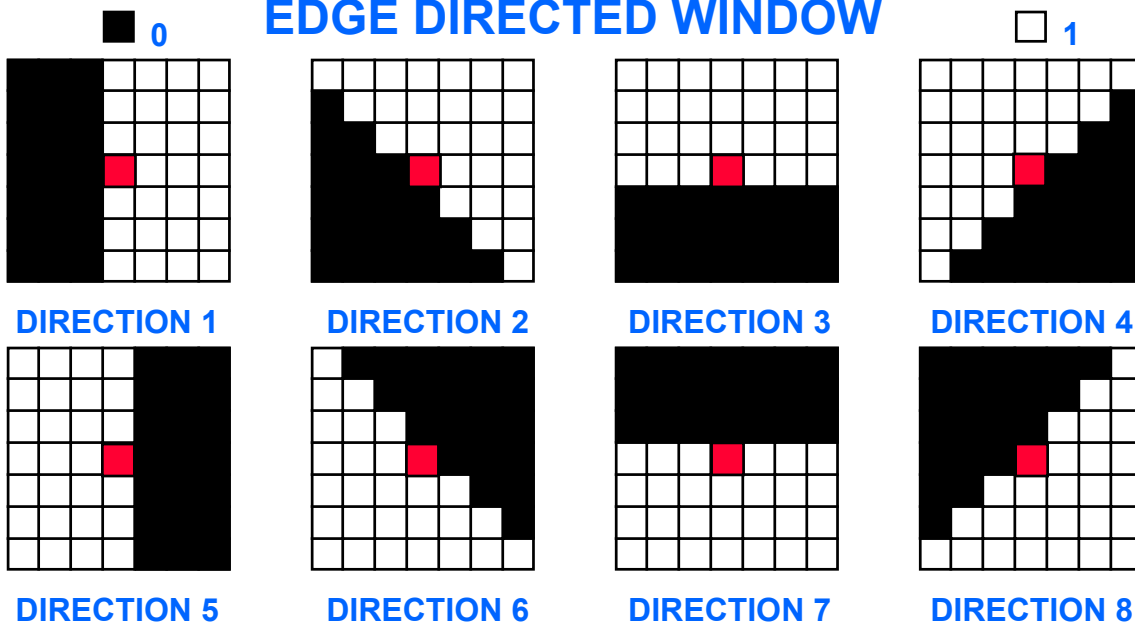
POLARIMETRIC VECTORIAL SPECKLE LEE FILTER

$$[\hat{C}] = E([C]) - k[E([C]) - [C]]$$

EACH ELEMENT OF THE COVARIANCE MATRIX IS FILTERED

- BY THE SAME AMOUNT AVOIDING CROSS-TALK AND PRESERVING POLARIMETRIC INFORMATION AND CORRELATIONS
- SIMILAR TO THE MULTI LOOK PROCESSING BY AVERAGING THE COVARIANCE MATRICES OF NEIGHBORING PIXELS
- BY WEIGHTING THE COVARIANCE MATRIX OF THE CENTER PIXEL OF THE SLIDING WINDOW WITH THE MEAN OF COVARIANCE MATRICES FROM SELECTED NEIGHBORING PIXELS PRESERVING SPATIAL RESOLUTION, FEATURES, EDGES ... REFINED LEE FILTER

EDGE DIRECTED WINDOW



LOCAL HETEROGENEITY &
NOISY EDGE BOUDARIES

THE EDGE DIRECTED
WINDOWS ARE USED TO
COMPUTE THE LOCAL MEAN
AND VARIANCE

POLARIMETRIC LEE FILTER

$$[\hat{C}] = E([C]) - k[E([C]) - [C]]$$

$$k = \frac{\text{var}(S)}{\text{var}(S_S)} = \frac{CV_{S_S}^2 - \sigma_v^2}{CV_{S_S}^2 [1 + \sigma_v^2]}$$

FOR EACH PIXEL, THE k VALUE IS COMPUTED
IN AN EDGE DIRECTED WINDOW



OP-AIRFIELD L-Band

POLARIMETRIC SPECKLE FILTERING IS NOT AN EXACT SCIENCE SUBJECTIVE, IMAGE DEPENDENT

Quantitative Criteria (J.S. Lee - IGARSS 98)

- Speckle Reduction (E.N.L)
- Edge Sharpness Preservation
- Line and Point Target Contrast Preservation
- Retention of Mean Values in Homogeneous Regions
- Retention of Texture Information
- Retention of Polarimetric Information (co, cross-correlations)
- Computational Efficiency
- Implementation Complexity

$$[\hat{C}] = E([C]) - k[E([C]) - [C]]$$

THE POLARIMETRIC SPECKLE LEE FILTER
IS TODAY A GOOD COMPROMISE

$$[\mathbf{C}] = \underline{\mathbf{y}}\underline{\mathbf{y}}^{*T} \quad \xrightarrow{\text{FILTER}} \quad [\hat{\mathbf{C}}] = \underline{\hat{\mathbf{x}}}\underline{\hat{\mathbf{x}}}^{*T}$$

AVERAGING DATA



SECOND ORDER STATISTICS



COVARIANCE / COHERENCY MATRICES

SMOOTHING AVERAGING



CONCEPT OF THE
DISTRIBUTED TARGET

