**My Note:**

**SAR Signal Scattering Over Inundated Regions**

**Types of Surface Scattering in SAR Imagery**

1. **Smooth Surface Scattering**
   * Appears dark in SAR imagery due to low backscatter.
2. **Rough Surface Scattering**
   * The rougher the surface, the more the signal is scattered.
3. **Double Bounce Scattering**
   * A characteristic of urban surfaces where two smooth surfaces create an angle, causing a bright appearance in SAR imagery.
   * Also occurs in vegetated areas, especially with L-band HH polarization.

**SAR Characteristics: Wavelength, Polarization, and Incidence Angle**

**1. Wavelength**

* **L-band** (longer wavelength):
  + Penetrates deeper through vegetation and can measure inundation beneath forest canopies.
  + Ideal for studying flood conditions in densely vegetated regions.
* **C-band** (shorter wavelength):
  + Suitable for areas with low biomass, such as agricultural fields and sparse vegetation.
  + Less penetration compared to L-band.
* **Penetration Factor:**
  + The longer the wavelength, the greater the penetration ability.

**2. Polarization**

* **Definition:** The orientation of the electric field of the SAR signal, which can be either vertical (V) or horizontal (H).
* **Common Polarization Combinations:**
  + **HH (Horizontal Transmit, Horizontal Receive):**
    - Best for detecting flooded vegetation in densely vegetated areas.
    - With L-band, HH can penetrate through the canopy to detect water beneath.
  + **HV (Horizontal Transmit, Vertical Receive):**
    - More sensitive to volume scattering and is useful for identifying vegetation cover.
* **RGB Composite of Different Polarizations:**
  + Combining HH, HV, and VV polarizations helps enhance interpretation in SAR imagery.

**3. Effect of Incidence Angle Variation**

* **Backscatter Variation:**
  + Every surface feature has a unique backscatter pattern depending on the incidence angle.
  + A smooth surface at certain angles may appear brighter than expected.
* **Vegetation Misinterpretation:**
  + In some images, dense vegetation can appear similar to open water due to low scattering.
  + Surface wind can also alter the backscatter signal, making open water detection more challenging.
* **Techniques for Clarity:**
  + **HH/HV ratio** can help differentiate between water and vegetation.
  + **HV polarization** is better for identifying open water.
  + **Texture measurements** can help distinguish flooded areas from bright urban surfaces.

**Freely Available SAR Data Sources**

* **ALOS-1**
* **Sentinel-1**
* **BIOMASS Mission**
* **NISAR (NASA-ISRO SAR Mission)**
* **Seasat**

**Claudi Advance Note Built on Mine**

**SAR Signal Scattering Over Inundated Regions**

**1. SAR Signal Scattering Mechanisms**

**1.1 Specular (Smooth Surface) Scattering**

* Occurs when the surface roughness is significantly smaller than the radar wavelength.
* Primary mechanism: Coherent reflection away from the sensor.
* Electromagnetic energy is reflected in a single direction following Snell's law.
* Results in minimal backscatter return to the sensor.
* Characteristic dark appearance in SAR imagery.
* Common examples: Standing water, calm water bodies, very smooth bare soil.

**1.2 Rough Surface Scattering**

* Manifests when surface variations are comparable to radar wavelength.
* Produces diffuse scattering in multiple directions.
* Backscatter intensity increases with surface roughness.
* Rayleigh criterion defines critical roughness threshold.
* Examples: Plowed fields, rough soil surfaces, choppy water.

**1.3 Volume Scattering**

* Occurs within a medium rather than at a surface.
* Multiple scattering events within the medium's structure.
* Key characteristics:
  + Penetration depth depends on wavelength and medium properties.
  + Signal attenuation increases with medium density.
  + Multiple internal reflections create complex backscatter patterns.
* Common in:
  + Forest canopies (multiple vegetation layers).
  + Dry snow pack (ice crystal matrices).
  + Dry sand (internal grain structures).
* Factors affecting volume scattering:
  + Medium density and structural complexity.
  + Dielectric properties of the medium.
  + Signal wavelength and polarization.
  + Moisture content (affects penetration depth).

**1.4 Double Bounce Scattering**

* Results from two specular reflections between perpendicular surfaces.
* Creates strong dihedral corner reflector effect.
* Produces high-intensity returns in SAR imagery.
* Particularly prominent in:
  + Urban environments (building-ground interfaces).
  + Flooded forests (water-trunk interfaces).
* Enhanced by smooth surface conditions.
* Highly dependent on incident angle.

**2. SAR System Parameters and Their Effects**

**2.1 Wavelength Bands**

* **L-band (λ ≈ 23.5 cm)**
  + Superior penetration capabilities.
  + Optimal for forest biomass assessment.
  + Enhanced flood detection under canopy.
  + Lower sensitivity to atmospheric effects.
  + Examples: ALOS PALSAR-2, NISAR.
* **C-band (λ ≈ 5.6 cm)**
  + Balanced penetration and surface sensitivity.
  + Ideal for agricultural monitoring.
  + Effective for surface deformation studies.
  + Good temporal coherence.
  + Examples: Sentinel-1, Radarsat-2.
* **X-band (λ ≈ 3.1 cm)**
  + High spatial resolution capability.
  + Superior for urban monitoring.
  + Limited penetration depth.
  + Examples: TerraSAR-X, COSMO-SkyMed.

**2.2 Polarization Configurations**

* **HH (Horizontal-Horizontal)**
  + Enhanced penetration through vertical structures.
  + Superior for flood detection under vegetation.
  + Strong double-bounce returns.
  + Optimal for soil moisture under moderate vegetation.
* **HV (Horizontal-Vertical)**
  + Sensitive to volume scattering mechanisms.
  + Effective for biomass estimation.
  + Good indicator of vegetation structure.
  + Reduced sensitivity to surface roughness.
* **VV (Vertical-Vertical)**
  + Enhanced sensitivity to vertical structures.
  + Optimal for maritime applications.
  + Strong surface scattering component.
  + Good for crop monitoring.

**2.3 Incidence Angle Effects**

* **Near Range (steep angles):**
  + Enhanced penetration capability.
  + Higher sensitivity to surface roughness.
  + Reduced shadowing effects.
  + Better for urban applications.
* **Far Range (shallow angles):**
  + Increased sensitivity to surface features.
  + Enhanced volume scattering contribution.
  + Greater atmospheric path length.
  + Better for soil moisture applications.

**3. Advanced Analysis Techniques**

**3.1 Water Body Detection**

* Multi-temporal analysis to reduce false detections.
* Polarimetric ratios (HH/HV) for ambiguity reduction.
* Texture analysis for differentiation from smooth surfaces.
* Consideration of wind effects on water surfaces.
* Vegetation can appear similar to open water due to low scattering, requiring image ratios to clarify.

**3.2 Urban Area Analysis**

* Exploitation of corner reflector characteristics.
* Integration of textural measures.
* Use of polarimetric decomposition.
* Time series coherence analysis.
* Flooded urban areas can appear very bright in SAR imagery, similar to vegetation, requiring additional differentiation techniques.

**4. Available SAR Data Sources and Characteristics**

* **Sentinel-1**
  + C-band, dual polarization.
  + 6/12-day repeat cycle.
  + Global systematic acquisition.
* **ALOS-2 PALSAR-2**
  + L-band, full polarimetric capability.
  + 14-day repeat cycle.
  + Variable acquisition modes.
* **Upcoming Missions**
  + **NISAR (NASA-ISRO SAR Mission):** L/S-band, dual polarization.
  + **Biomass:** P-band, forest focus.
  + **ROSE-L:** L-band, vegetation emphasis.

**5. Technical Processing Requirements**

**5.1 Pre-processing Steps**

1. Radiometric calibration.
2. Multi-looking for speckle reduction.
3. Terrain correction using DEM.
4. Atmospheric correction (when applicable).
5. Geometric co-registration.

**5.2 Quality Control Parameters**

* Temporal coherence threshold: > 0.3.
* Spatial baseline constraints.
* Atmospheric phase screen evaluation.
* Ground control point distribution.
* Error budget assessment.