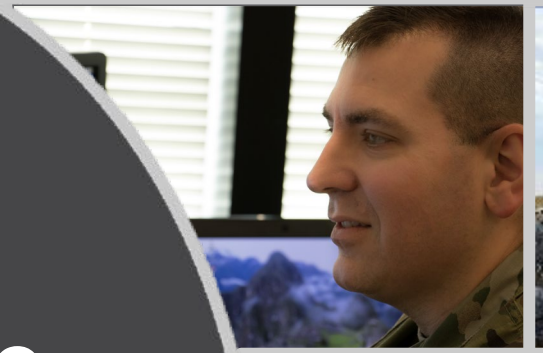
Controlling Surface Roughness to Enhance or Degrade Image Appearance in Synthetic Aperture Radar (SAR)





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Agenda

- Radar
- Synthetic aperture radar (SAR)
- Factors affecting SAR image
  - Material properties
  - Radar-viewing angle and surface geometry
  - *Surface roughness*
- Surface roughness
  - Specular reflection
  - Diffuse reflection
  - Rayleigh criterion or Fraunhofer criterion
  - Controlling surface roughness

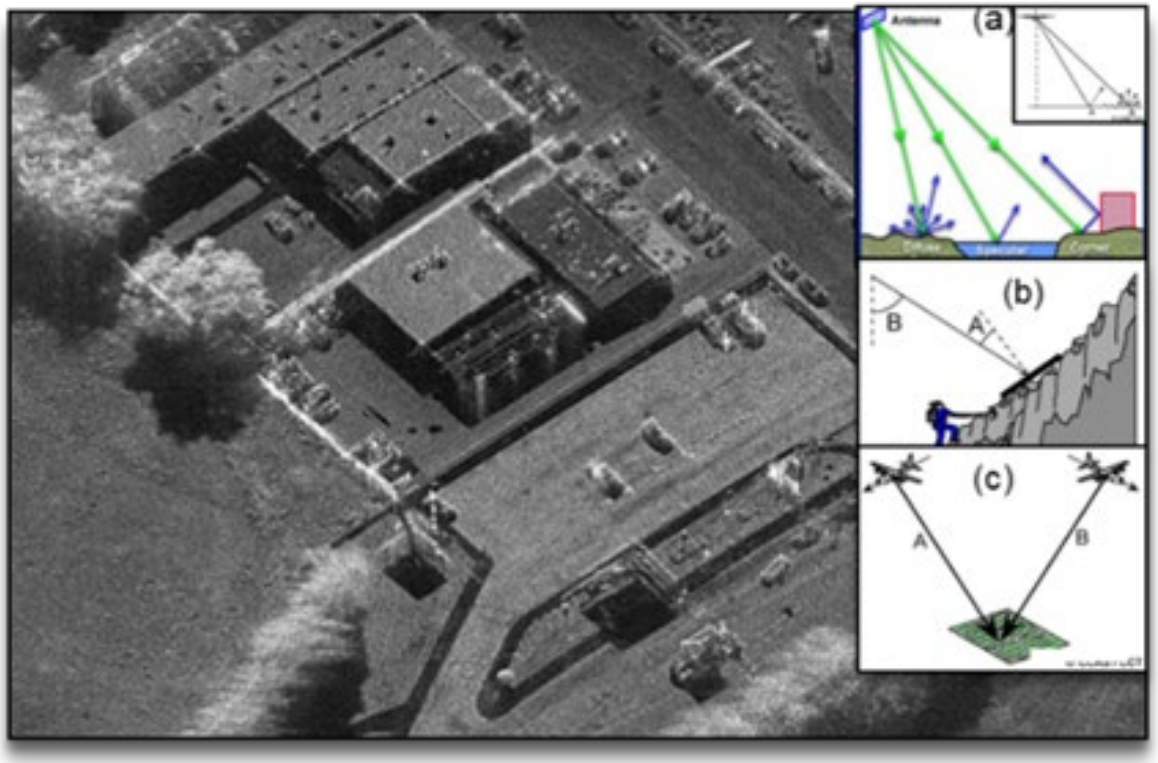

Figure 1: Effects of Surface Roughness, Viewing Angle, and Geometry [1].

Radar

SAR RADAR Band	Frequency Range (GHz)	Corresponding Wavelength Range(cm)
P	0.230 -1	130 - 30
L	1-2	30 - 15
S	2-4	15 - 7.5
C	4-8	7.5 - 3.75
X	8-12.5	3.75 - 2.40
Ku	12.5-18	2.40 - 1.67
K	18 -26.5	1.67 - 1.13
Ka	26.5- 40	1.13 - 0.75

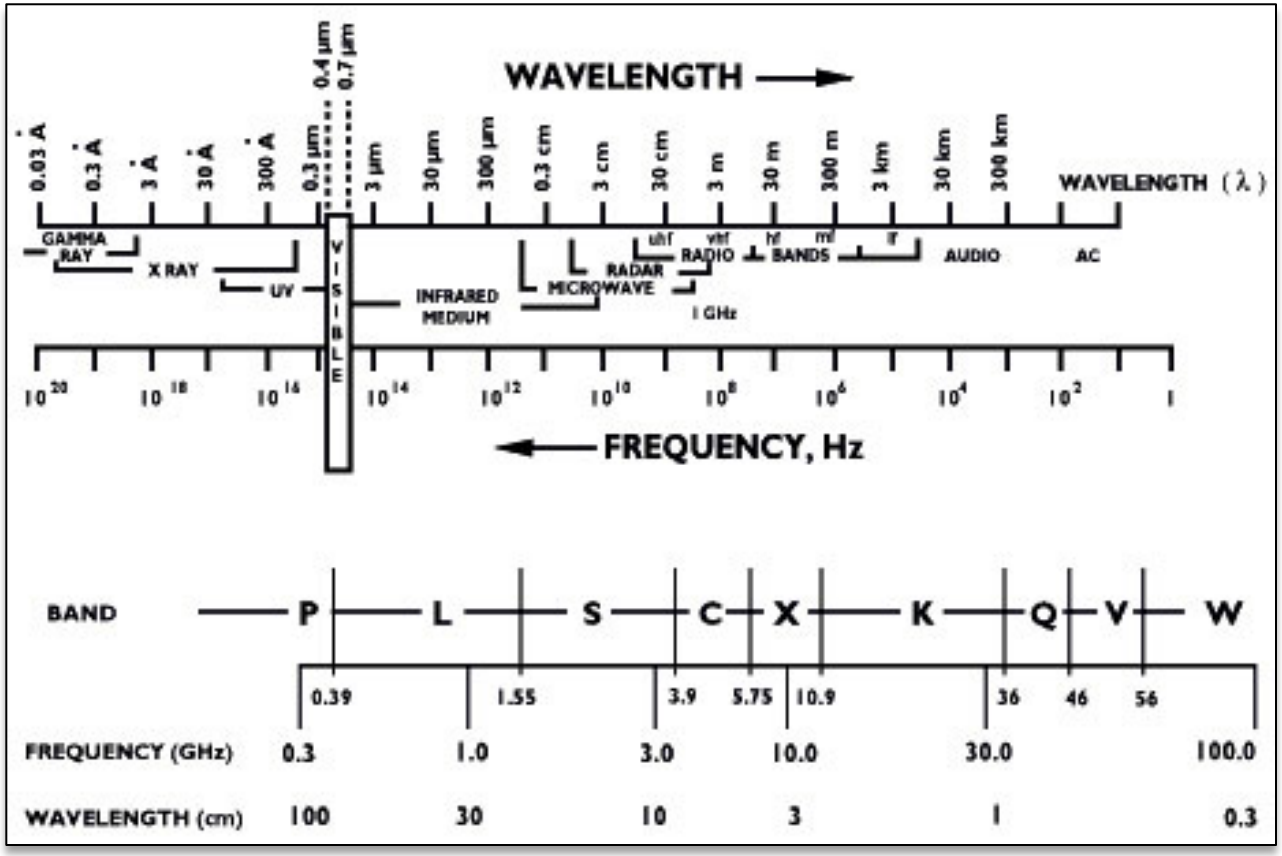

Figure 2: Electromagnetic (EM) Spectrum and Radar Wavelengths [2].

SAR [3]

- Can penetrate clouds, fog, dust, and other atmospheric obstructions
- Creates a large simulated aperture through motion of the platform
- Transmits EM waves toward the target and receives reflected EM waves back at the antenna

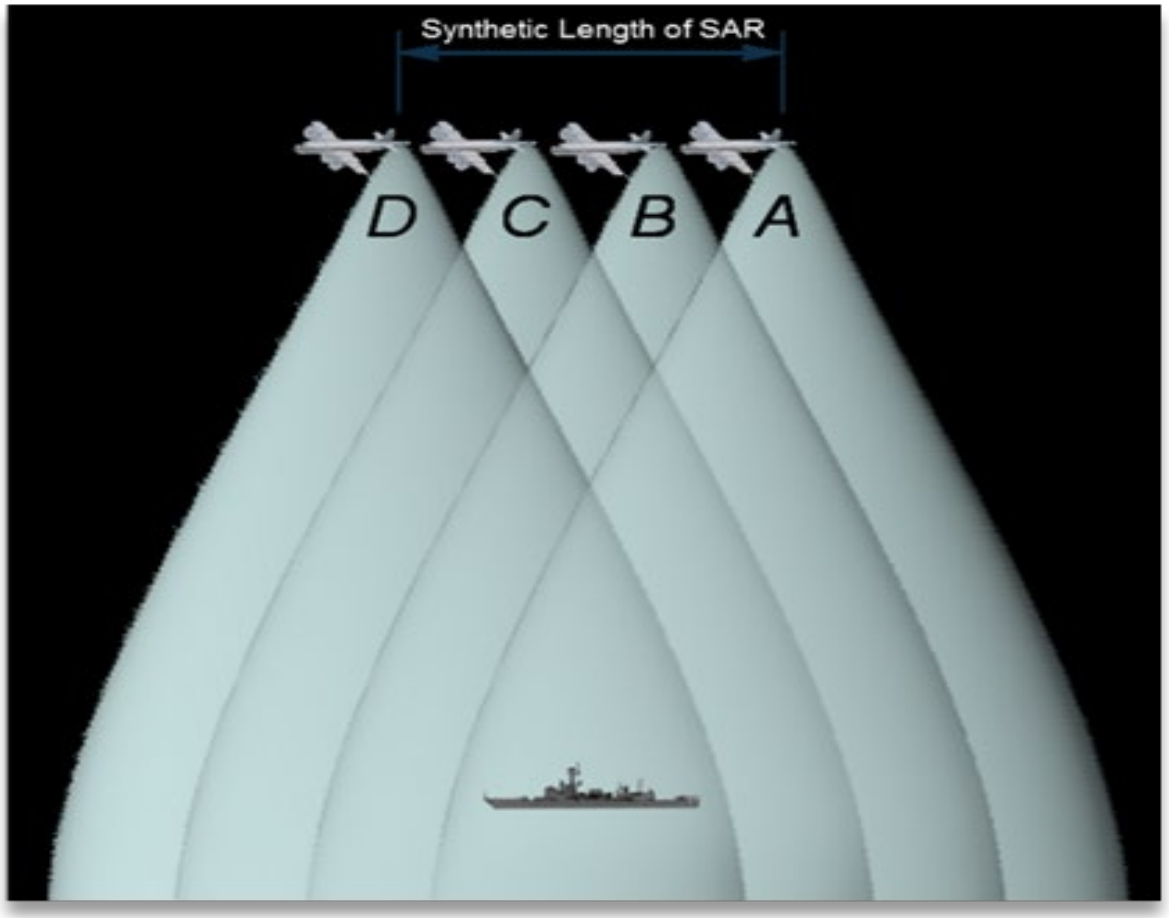

Figure 3: Example of SAR Collection From Airborne Asset [4].

Material Properties, Radar Viewing Angle, and Surface Geometry [5-7]

- Absolute permittivity
- Permeability
- Transmits EM waves toward the target and receives reflected EM waves back at the antenna
- Figure 4 (a)
  - Specular and diffuse reflection
- Figure 4 (b)
  - Radar-viewing angle and surface geometry effects
- Figure 4 (c)
  - Orientation of transmitted radar beam

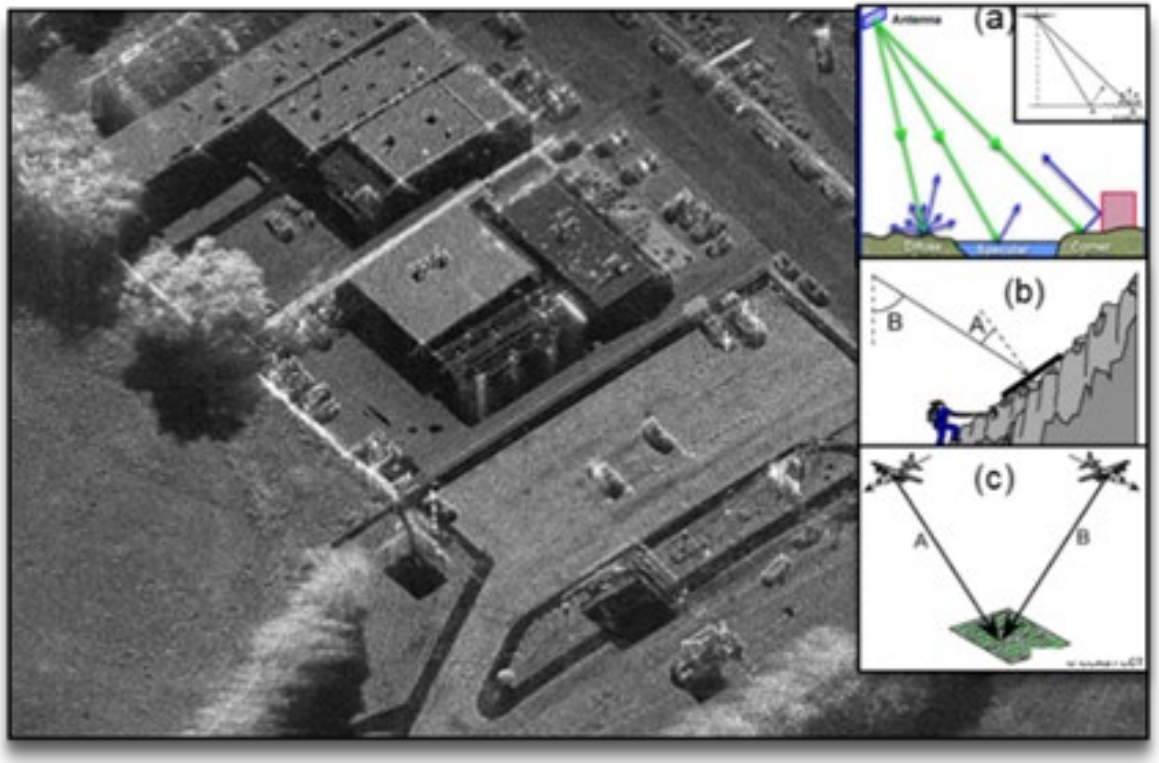

Figure 4: Effects of Surface Roughness, Viewing Angle, and Geometry [1].

Surface Roughness

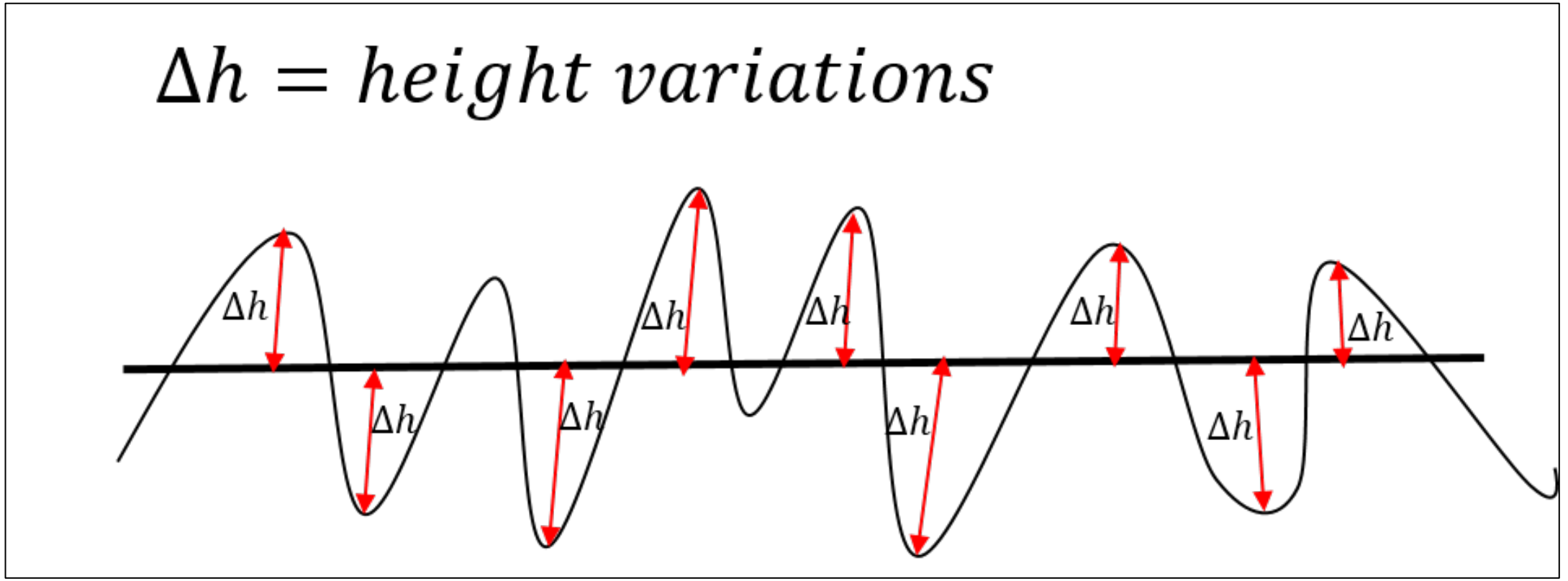

Figure 5: Surface Variations and Their Relation to Surface Roughness (Adapted From Reference [8]).

Surface Roughness (cont.)

- Smooth surface
  - Height variations less than radar wavelengths
  - Specular reflection
  - More of the energy goes away from the radar receiver
    - Darker tone
- Rough surface
  - Height variations close to radar wavelengths
  - Diffuse reflection
  - More of the energy goes toward the radar receiver
    - Brighter tone

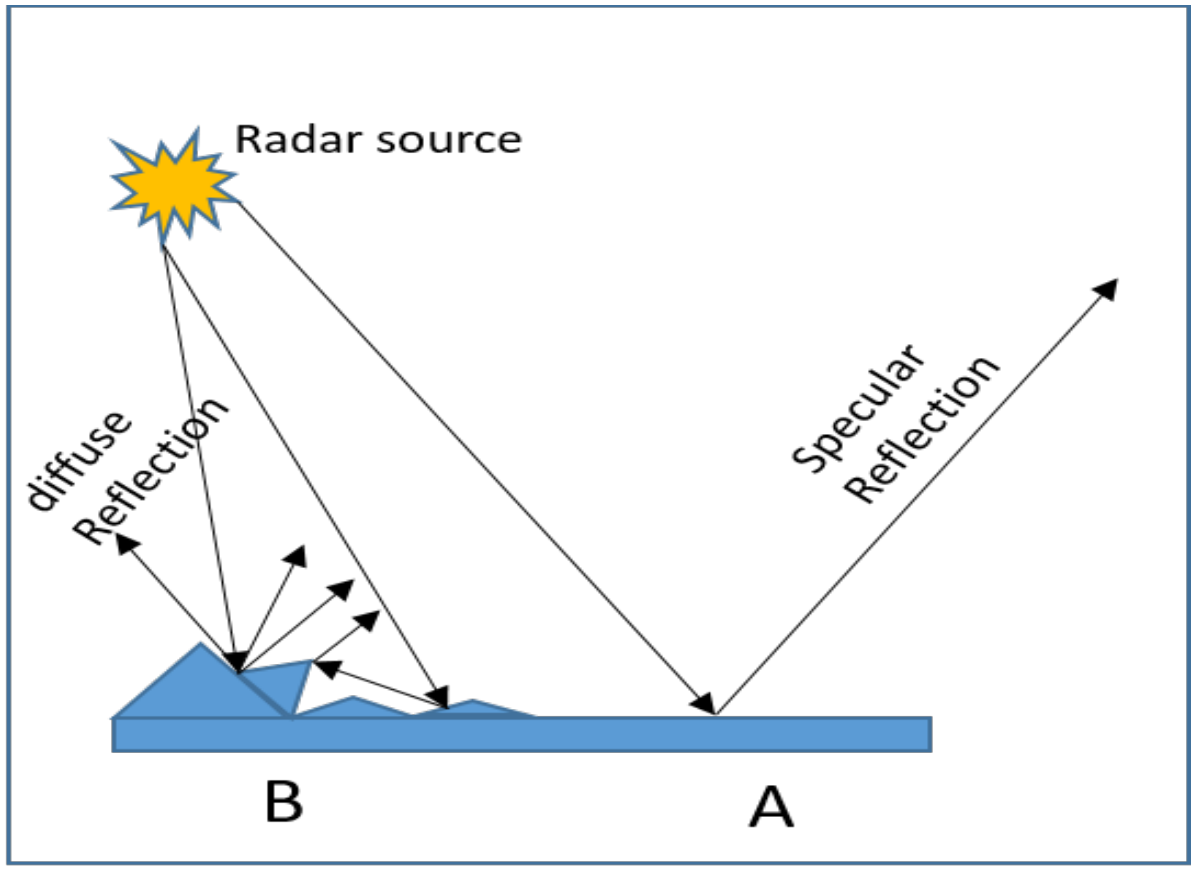

Figure 6: Surface Variations and Their Relation to Surface Roughness (Adapted From Reference [8]).

Rayleigh and Fraunhofer Criterion

- **Describes the relationship that must be satisfied for a smooth surface**
- **Δh is the height variations in the surface**
- **λ is the wavelength of the incoming radiation**
- **θ is the incidence angle**

Table 1: Rayleigh and Fraunhofer Criteria for Surface Smoothness [9]

Rayleigh Criterion	Fraunhofer Criterion
$\Delta h < \frac{\lambda}{8cos\theta}$	$\Delta h < \frac{\lambda}{32cos\theta}$

Stylus Profilometry [10]

- Measures surface roughness
- Optical profilometer consists of:
  - Detector
  - Sample stage
- Detector determines the location of the points on the sample
- Probe or the sample holder can move to get the required measurements

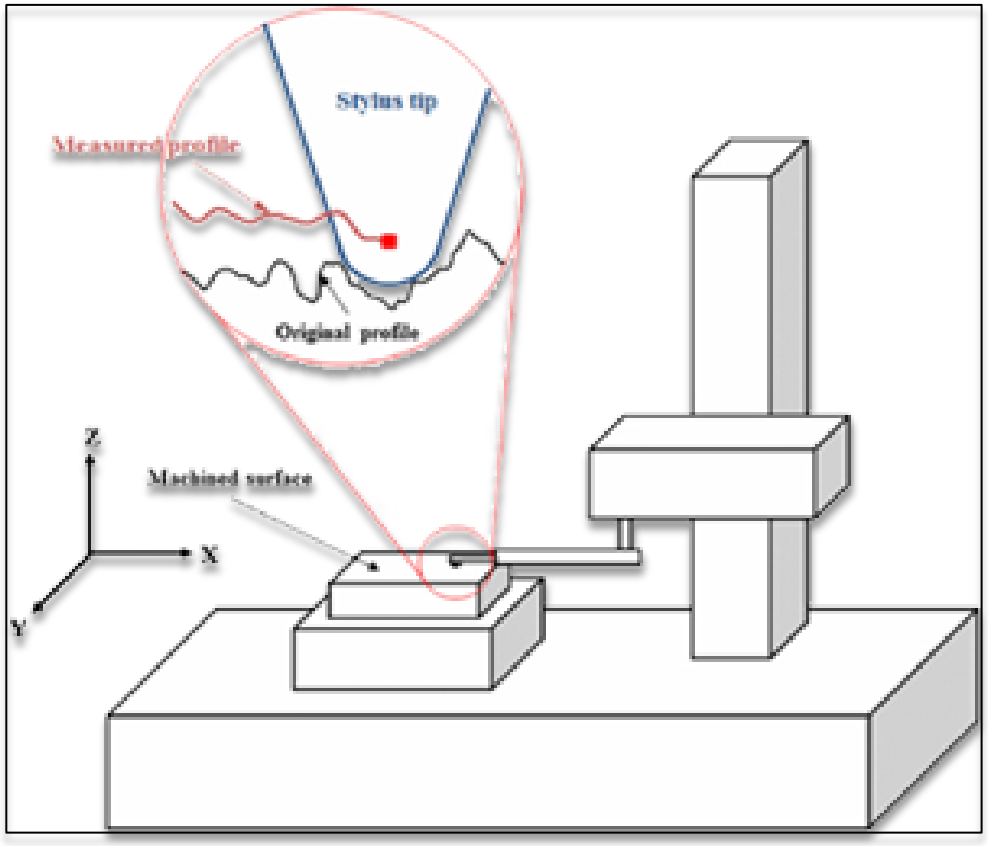

Figure 7: Schematic of a Stylus Profilometer [11].

Questions?

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