# Modeling Lunar Radar Scattering from Icy Regoliths

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# Abstract

The Apollo 15, 16, and 17 core tubes show that the uppermost few meters of the lunar regolith are interlaced layers of a fine grained powders and blocky crater ejecta. The layers of crater ejecta have dielectric constants in the range of 7-9 while the fine-grained powders has dielectric constant on the order of 2.7. These differences in dielectric constant, in turn, create radar reflections that are both refracted and reflected back through the space-regolith interface. Note that for a dielectric constant of 2.7 for the lunar regolith, radio waves incident on the lunar surface at the angle of 30-degrees from the normal will propagate in the regolith at an angle of 18-degrees. At the limb, radio waves incident on the lunar surface at an angle near 90-degrees from the normal will propagate in the regolith at an angle of about 37-degrees. These angles are within the range where radar backscatter is in the quasi-specular regime.

When these buried crater ejecta layers are modeled using Hagfors' formulation (Hagfors, 1963), echo powers match the behavior observed for average lunar backscatter at centimeter wavelengths for higher (30° to 90°) angles of incidence. In addition, Hagfors et al. (1965) conducted an experiment where the Moon was illuminated at 23-cm wavelength with circular polarization and the differences were observed in orthogonal linear polarizations. Modeling of these observations and assuming again that the buried crater ejecta scatter in a quasi-specular manner, echo differences in horizontal and vertical linear polarizations are in good agreement with the observations.

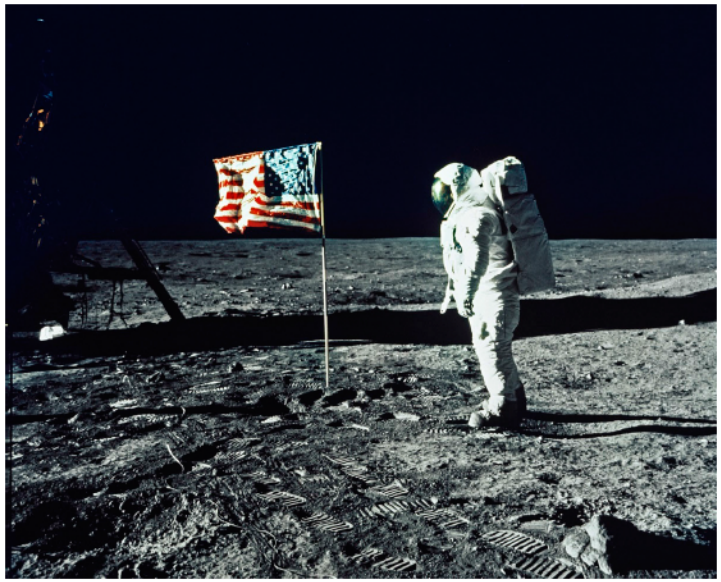
The data from Chandrayaan Mini-RF radar, which operated at S-Band (13cm) wavelength, and the Lunar Reconnaissance Orbiter (LRO) Mini-RF radar, which is operating at S-Band and X-Band (4-cm) wavelengths, provide an opportunity for a new examination of whether radar backscatter from buried crater ejecta behaves like a quasi-specular scatter. These radars reproduce the geometry of the Hagfors et al. (1965) observations as they transmit circular polarization and record echoes in horizontal and

# Contents

- Physical Properties of Apollo Core and Radar Scattering from Buried Crater Ejecta
- Test #1 –? Match Average Lunar Power versus Angle of Incidence ?
- Test #2 –? Match Linear Polarizations observed by Hagfors et al, 1965 ?
- Summary and Concluding Remarks

# Lunar Surface Panorama

Average Lunar Surface



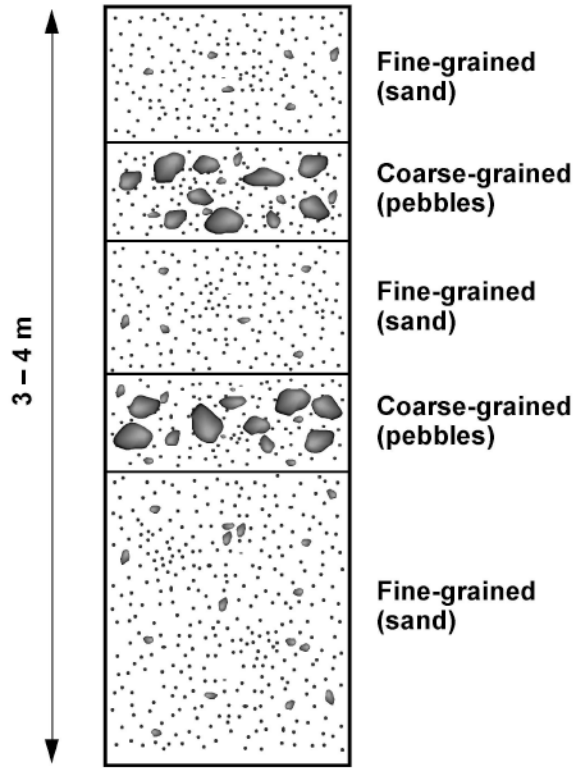
Apollo - Mare

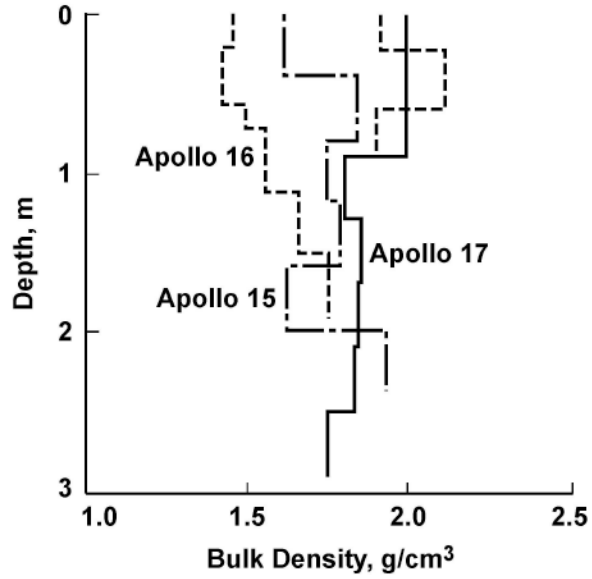
Times-10 70-cm Enhancement
Times-3 3.8-cm Enhancement

Surveyor-VII - Tycho Rim

**Lunar surface and regolith is a matrix of sand-like soil and rocks**

# Apollo Core Tubes

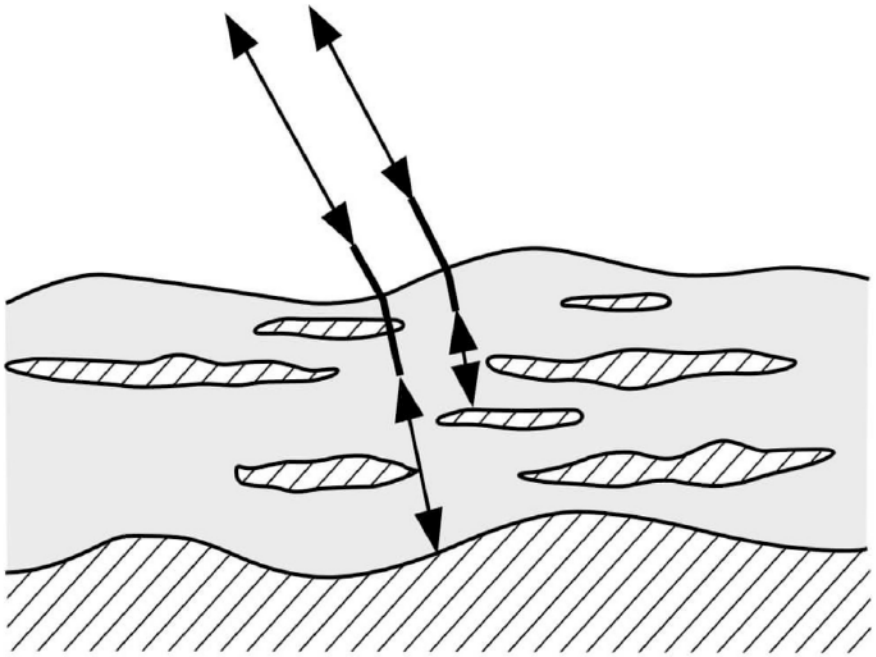


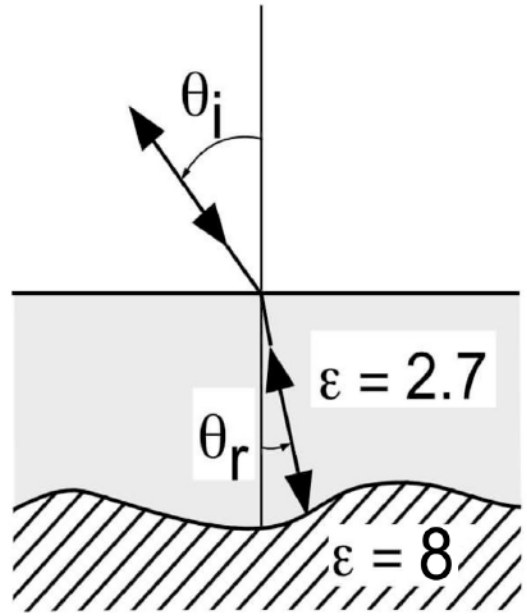

Bulk density as a function of depth
(Apollo 17 Preliminary Science Report)
(Mitchel, et al. 1973)

**Lunar regolith is a mixture of sand-like soil and rocks**
**Density differences will generate radar backscatter**

# Model for Radar Scattering from Buried Ejecta Layers



CONSOLIDATED SUBSURFACE LAYERS

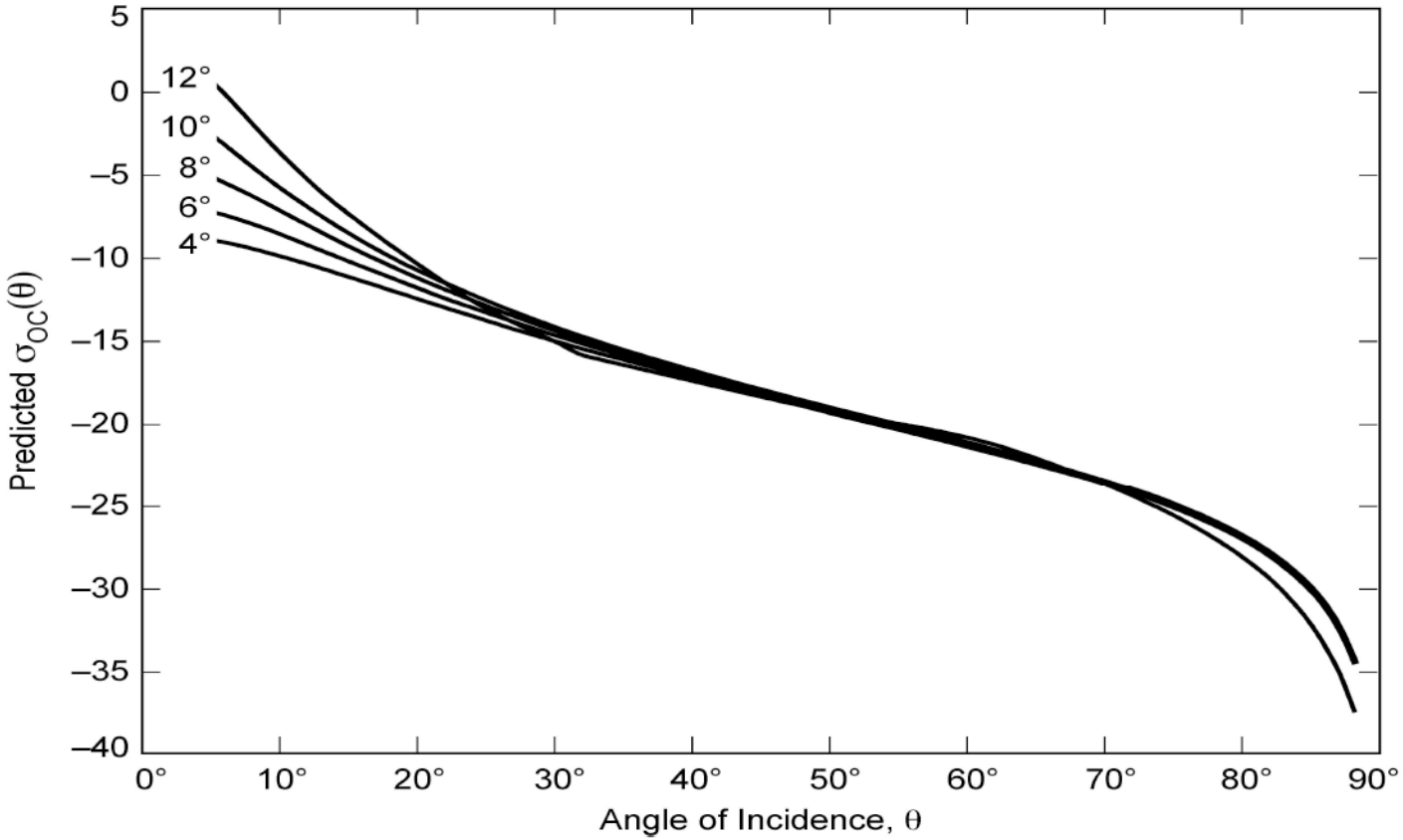



MODELLED SUBSURFACE LAYER

# Angles of Incidences - Radar Scattering from Buried Ejecta Layers

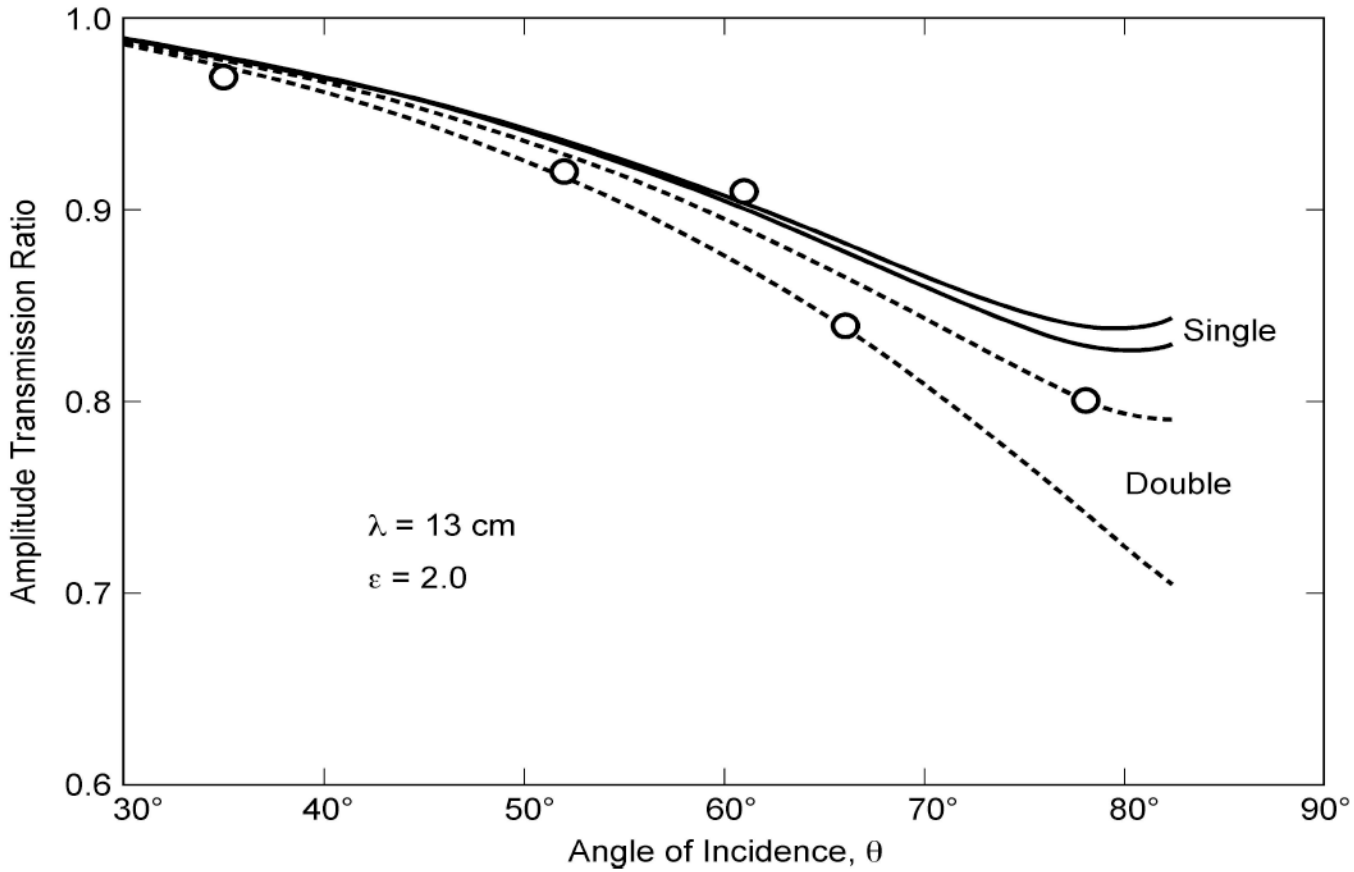
**UPDATE – Add Plot**
**Angle of Incidence vs**
**Theta refracted**

# Modeling for Radar Scattering from Buried Ejecta Layers



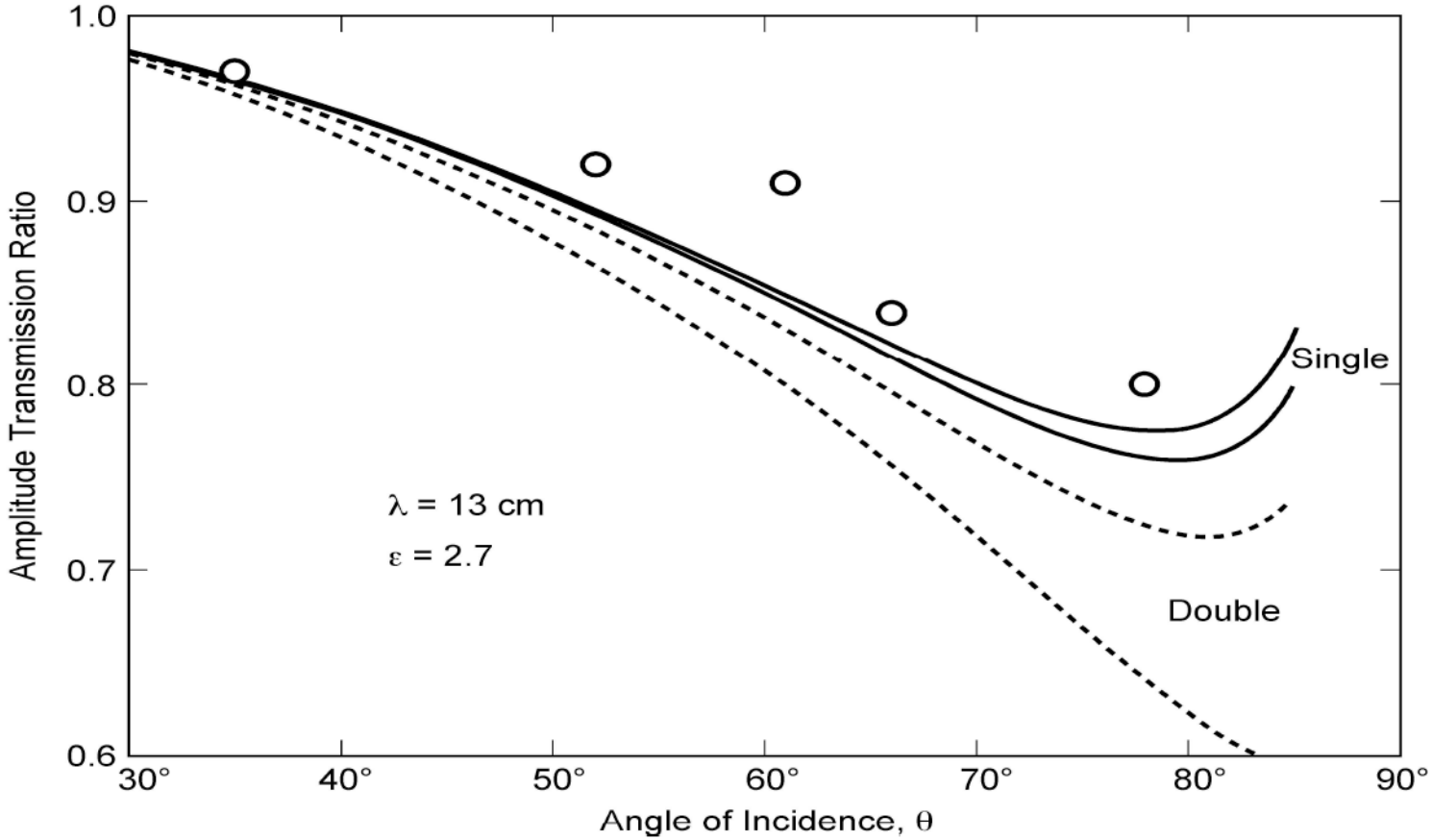

**Assuming buried layers backscatter quasi-speculaly**
**With standard Hagfors (1964) behavior,**
**modeled backscatter matches observed power vs. angle**

# Hagfors et al (1965) Modeling
# Epsilon = 2.0 / 13 cm / Good Match




**Dielectric Constant of 2.0 provides good match to observations**

# Hagfors et al (1965) Modeling
# Epsilon = 2.7 / 13 cm / Not Good Match




**Dielectric Constant of 2.7 does not match the observations**

# Summary / Concluding Remarks

- Density differences in the lunar regolith from buried crater ejecta can create radar backscatter that's refracted through the space-regolith interface.

- Assuming the these buried layers backscatter with power-vs-angle behavior modeled by the Hagfors (1964) scattering law, average high-angle lunar radar backscatter is obtained.

- Modeling horizontal and vertical polarization differences through the space-regolith interface, good results are obtained for a dielectric constant of 2.0
  - Note that a mixture of 90% dust with dielectric constant of 2.0 and 10% rocks with dielectric constant of 8.0, the resultant dielectric constant is 2.7, the accepted value for the dielectric constant of the Moon.

# References


- Hagfors, T. (1964), Backscattering from an undulating surface with application to radar returns from the Moon, J. Geophys. Res., 97, 13,319–13,346.
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- Hagfors, T., R. A. Brockelman, H. H. Danforth, I. Hanson, and G. M. Hyde (1965), Tenuous surface layer on the Moon: Evidence derived from radar observations, Science, 150, 1153–1156.