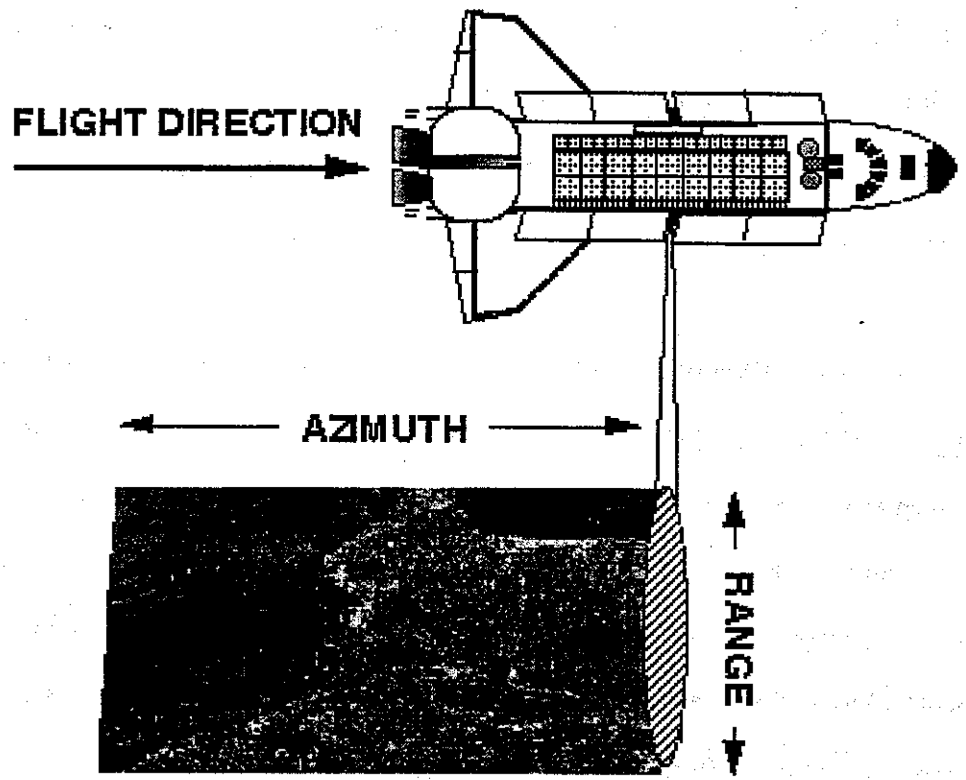
Microwave Sensors – Radar

We first will consider radar systems. These instruments are called "active" sensors because they carry with them their own illumination, rather than relying on reflected solar energy. In addition, the atmosphere is nearly transparent at these wavelengths, whether or not there are clouds present. Radars are thus called day/night all weather sensors, because they can be used independently of the usual restrictions on illumination and atmospheric state.

There are, however, disadvantages to these systems also. Since they must supply their own light, they must generate powerful beams of microwave energy in space. They also require quite significant data processing on the ground to convert the radar echoes into useful images.

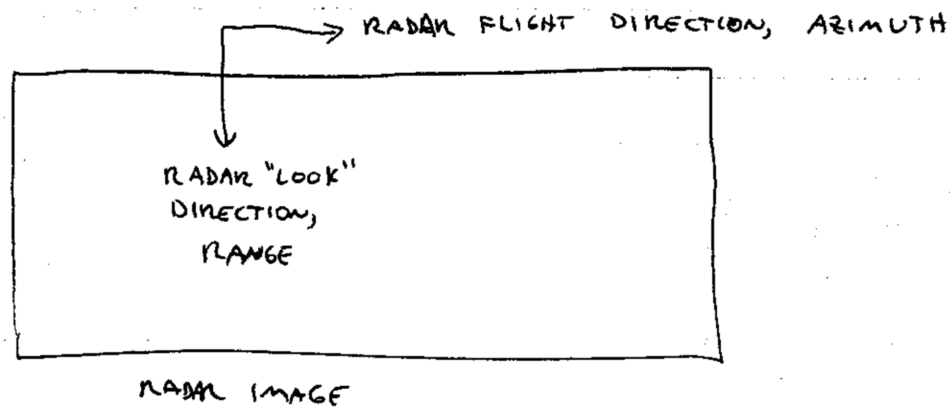
By the way, "radar" is an acronym for "Radio Detection and Ranging", where ranging here refers to the measurement of distance.


FLIGHT DIRECTION
AZIMUTH
RANGE

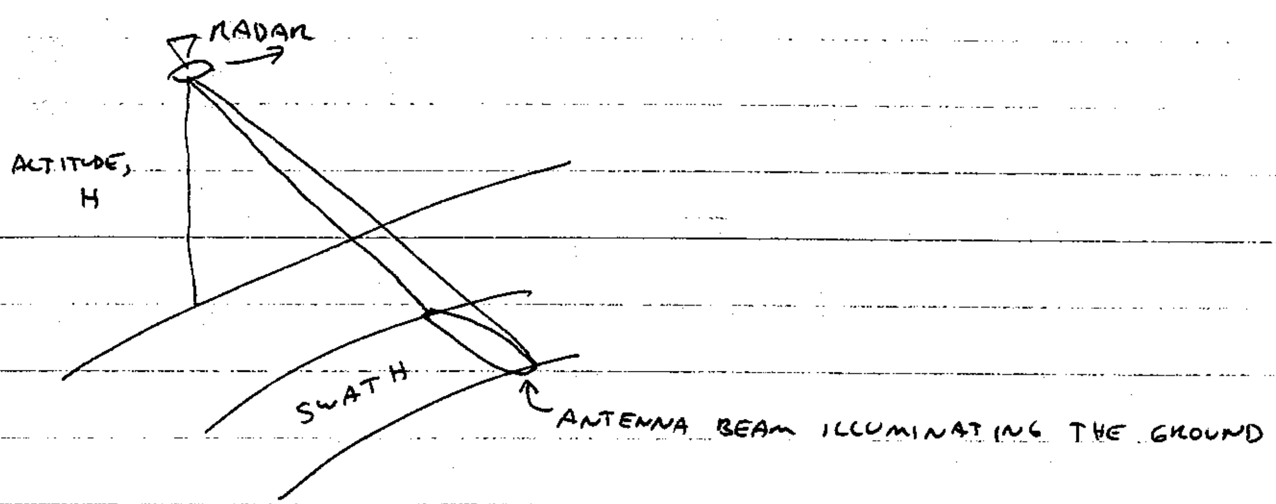
The fundamental measurement a radar system makes is a distance measurement, or range measurement. It is thus quite different than a photograph, which measures the distribution of reflected energy as a function of angle. Even though the final products look similar, they represent very different geometrical perspectives.

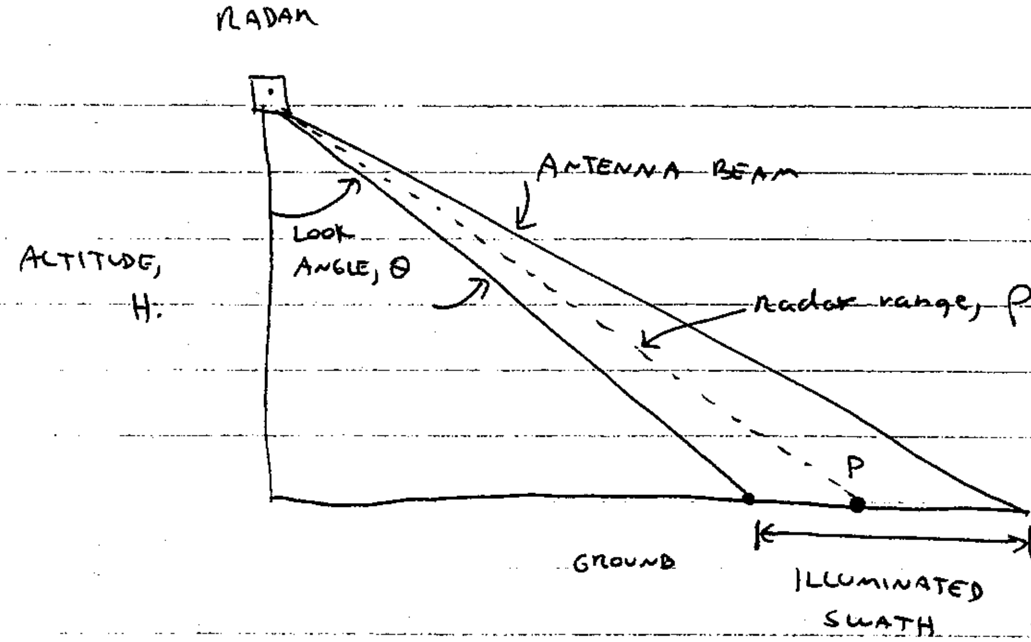
Radar terminology

Since radar has a vastly different method of data acquisition, it also has a very different set of terminology describing directions in the image.



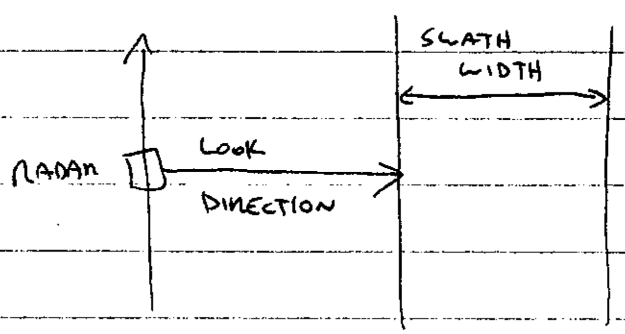
Resolution is given in the range, or across track direction, and the azimuth, or along-track direction.



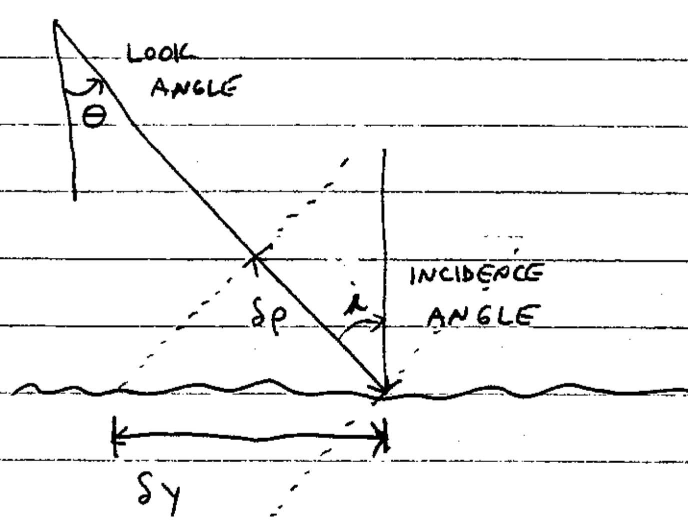


$$\cos\theta = \frac{H}{\rho}$$

side-looking geometry, looking into line of flight



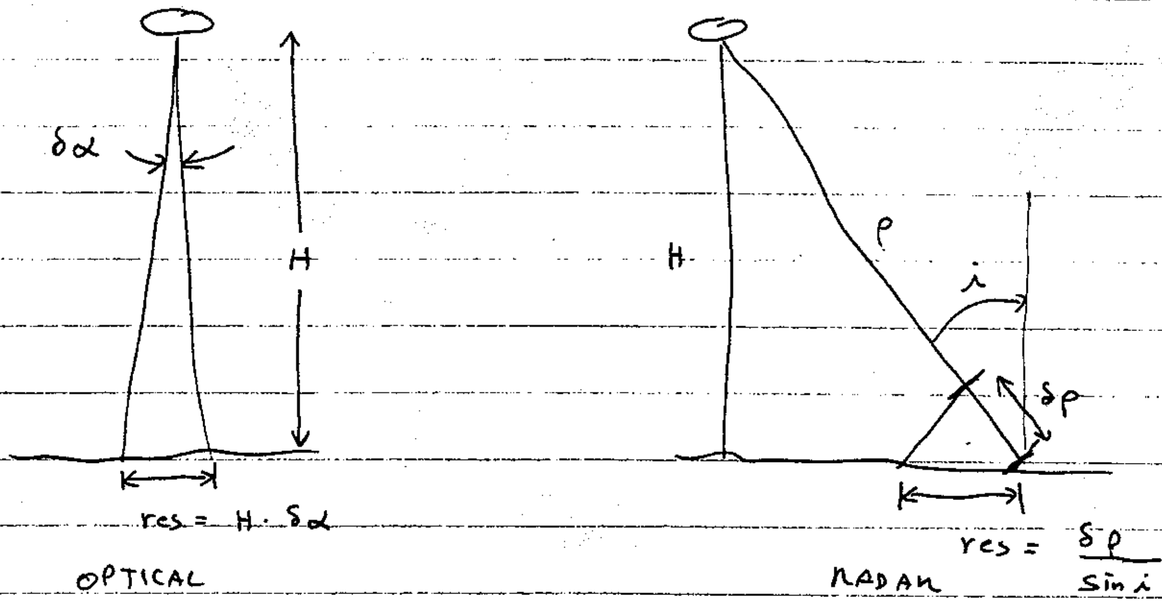
TOP VIEW SIDE LOOKING GEOMETRY



$$\delta y = \frac{\delta\rho}{\sin\theta} = \frac{\delta\rho}{\sin i}$$

↑ FLAT EARTH ONLY

The resolution for a radar system has to do with its ability to discriminate distance, not angle. Therefore the dependence of resolution on viewing geometry is quite different than for optical instrumentation:



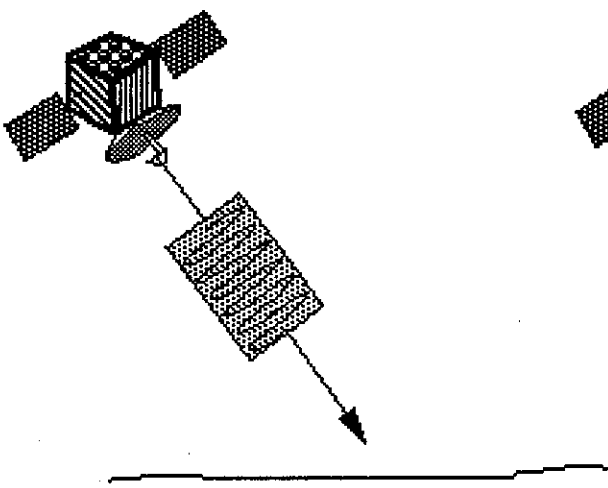
Note that the radar resolution is independent of distance or height, while for the camera-like instrument the resolution is proportional to height. However, for the radar case, as the distance, or range, increases, the signal level drops in strength quickly, make the resulting images low in quality.

Scattering

The radar works by sending out a pulse and recording the reflected energy. Thus to interpret a radar image it is important to know something about scattering from a surface.

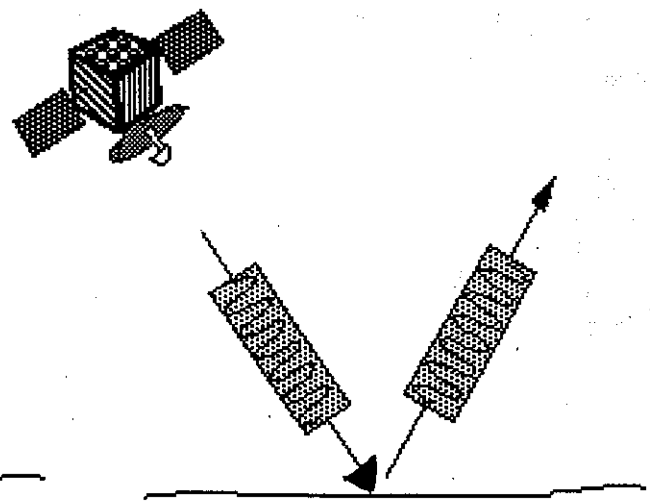
(1)

The radar sends a pulse toward the surface.



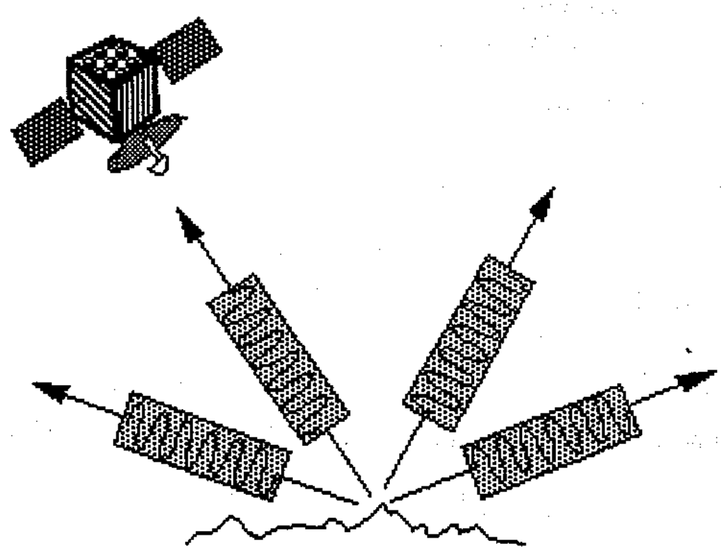
(2)

If the surface is quite flat, most of the energy is scattered away from the radar.



(3)

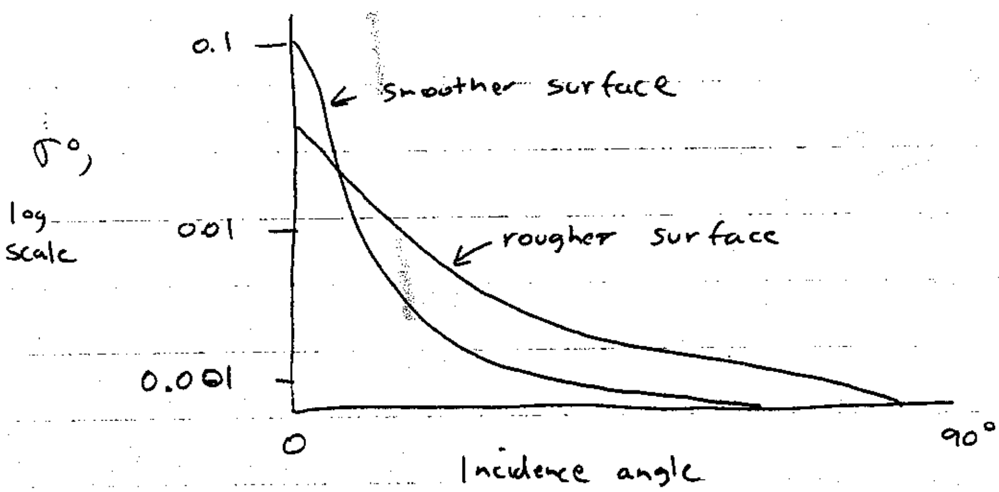
But for rougher surfaces, energy is reflected diffusely in all directions, including back toward the radar.



Therefore, one interpretation of brightness in a radar image is roughness, the brighter a surface appears then the rougher it is. And since our scattering is dominated by wavelength-scale structures, we are usually sensitive to objects and roughness from 1cm – 1m in size.

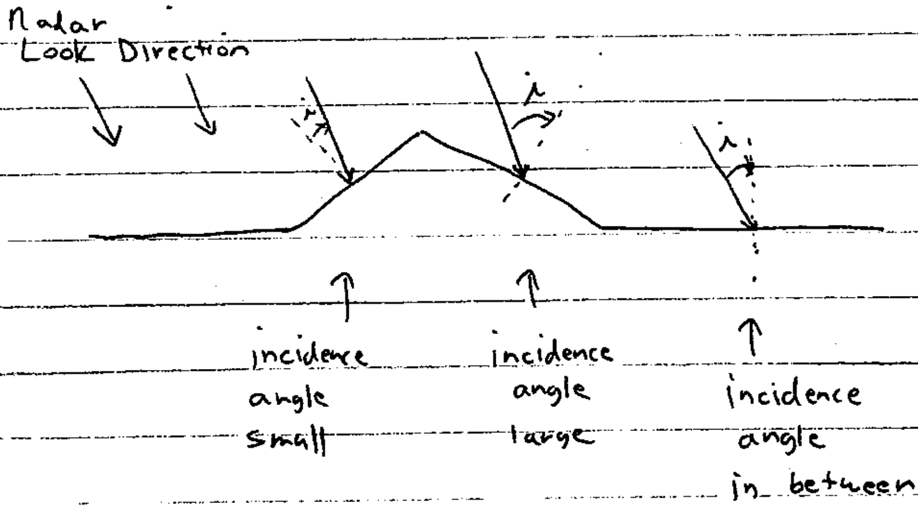
Since we are most often interested in energy reflected back to the radar and not in the rest of the reflected signal, we use special terms to refer to just this component. The "radar brightness" of a surface is called <u>normalized cross-section</u>, and denoted σ^o, or sigma-zero. It is the ratio of the intensity of energy from a given resolution element ("resel") in the backscatter direction to that which would be measured from a perfect metallic sphere of the same projected area as the resel.

σ^o is a function of many things, for us the most important being surface terrain types, wavelength, and angle. A typical plot of σ^o is

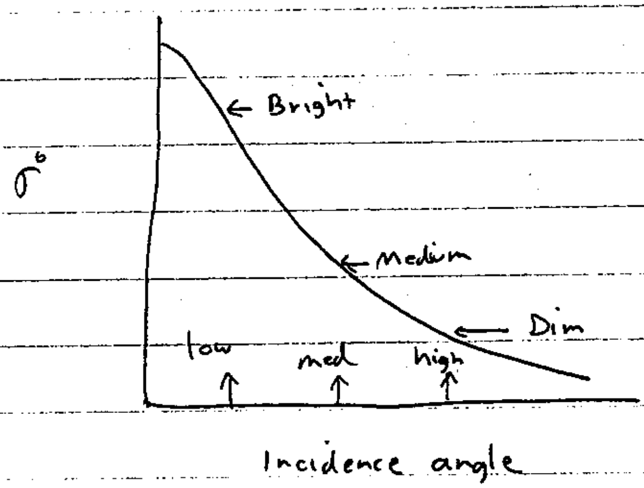


σ^o always decreases monotonically with angle. What does that mean for imaging surfaces with terrain?

Let's consider imaging a surface with a single mountain on it, as in the figure below:



So, what brightness would we expect in each of these regions?



Thus the mountain would appear brighter on the side facing the radar, and dimmer on the side away from the radar, than the surrounding flat terrain. This shading makes radar images quite sensitive to topographic features, so they are quite useful for geologic mapping.

Finally, we should note something about the dependence of σ^{o} on wavelength. Since for most surfaces the effective roughness increases as the wavelength decreases, we would expect images to get brighter as the wavelength is decreased. This in fact usually happens.

Example:

A radar with 1 cm, 10 cm, and 1 m wavelengths images a surface with considerable roughness at 1 and 10 cm but that is relatively smooth at 1 m. Its cross-section (expressed as σ°) would be high in the 1 cm and 10 cm images and would appear dim at 1 m.

Such a surface might be a field strewn with 10 cm rocks and smaller pebbles.

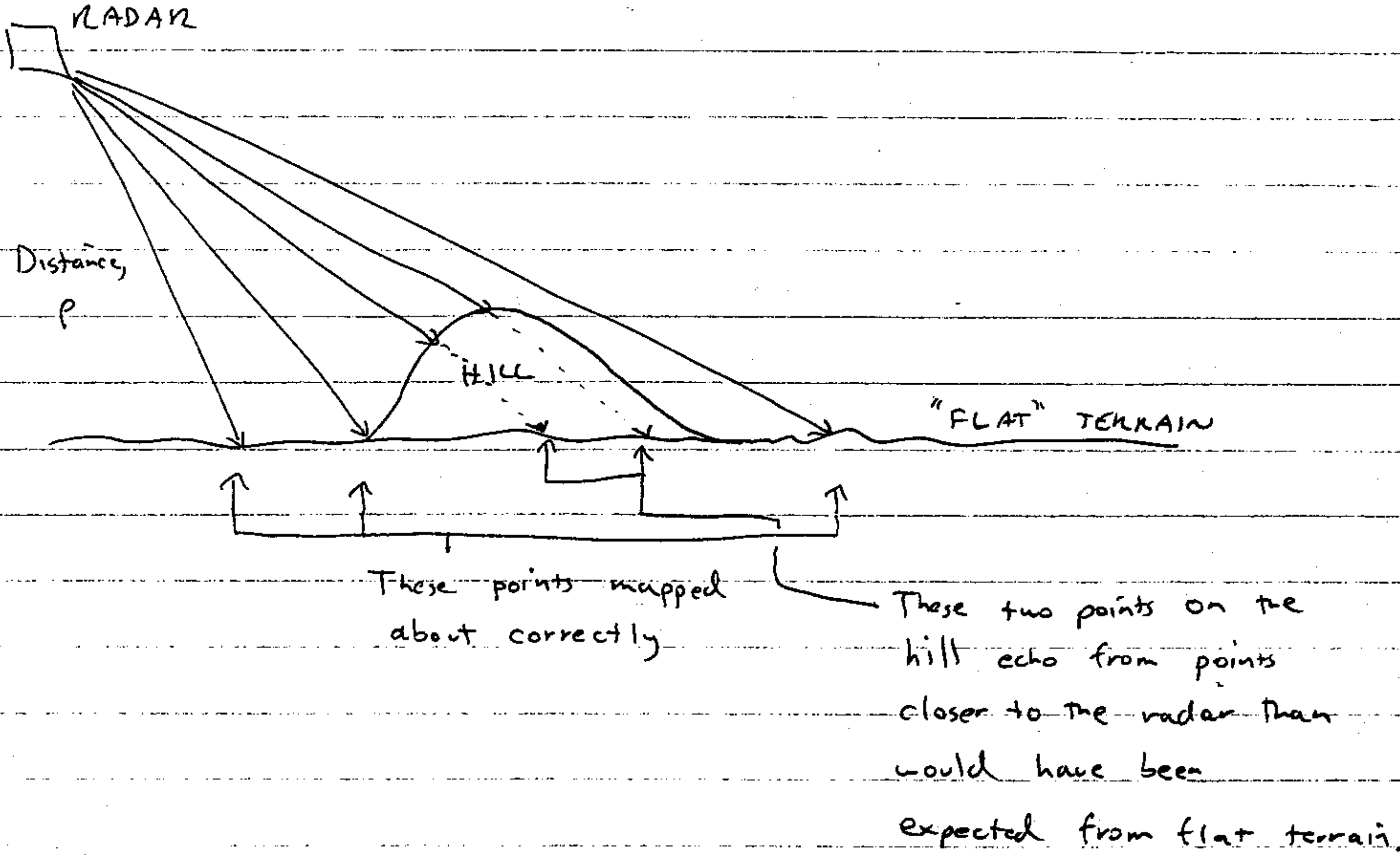
Terrain type effects σ°, largely through effective roughness mechanisms. Some terrain types and typical σ° values are:

Forest	0.1 - 0.3
Grassland	0.03
Bare agricultural field	0.01
Cornfield	0.1
Alluvial surface	0.01 - 0.03
Playa	0.001 - 0.01
Ocean	0.001 - 0.1

All these values are functions of wavelength. Typical values are given.

The final instrument characteristic we need to introduce for imaging radar systems is the distortion of the imaged area that is due to the radar mapping distances rather than angles. This leads to the phenomenon called <u>foreshortening</u>, or in severe cases, <u>layover</u>.

Why does this occur?



The effect of this is to have the tops of hills appear "closer" to the radar than they would have appeared in the absence of topography. Thus the front sides of hills are foreshortened, while the back sides are stretched out. Combining this geometrical effect with the brightness modulation described earlier gives mountains a distinct and peculiar effect in radar images.