Homework #1

SOLUTION

Assigned Jan. 26, 2018

Due Friday Feb. 2, 2018

Geology 4113 (Remote Sensing)Homework #1

In the following show the equations you use and the algebra.

1) **Wavelengths and frequencies (10 points)**
   a) What is the wavelength in centimeters for a radar system operating at 15 GHz.
   b) What is the frequency in gigahertz of a system operating at a wavelength of 10 cm?

a) The wavelength is given by $\lambda = \frac{c}{\nu} = \frac{3\times10^{8}\,\mathrm{m/s}}{15\times10^{9}\,\mathrm{s}} = 2.0\times10^{-2}\,\mathrm{m} = 2.0\,\mathrm{cm}$

b) The wavelength is given by $\nu = \frac{c}{\lambda} = \frac{3\times10^{8}\,\mathrm{m/s}}{10\times10^{-2}\,\mathrm{m}} = 3\times10^{9}\,\mathrm{s}^{-1} = 3\,\mathrm{GHz}$

2) **Spatial resolution (10 points)**
   Assume that your eyes have the normal resolving power of 0.2 milliradians, and that you are on an aircraft at an altitude of 20 km. For objects on the ground with a high contrast, what is the minimum separation (in meters) at which you can resolve these targets?

$$L = \theta r = 0.2\times10^{-3}\,\mathrm{rad}\times2\times10^{4}\,\mathrm{m} = 4\,\mathrm{m}$$

Note I can just drop the radians when convenient because it is a "dimensionless" term -- really just (length/length). We just write rad as a kind of unit, to reminds ourselves what we have measured.

3) **LROC Narrow Angle cameras. (20 Points)**

a) (10 points) The Lunar Reconnaissance Orbiter Camera (LROC) now in lunar orbit consists of several components including two Narrow Angle Cameras which are "along-track" or "pushbroom" instrument like the ones discussed in class, using the spacecraft motion for the forward scanning. At an altitude of 50 km it obtains images with a resolution of 0.5 m. It orbits at a velocity of approximately 1.6 km/second. Find the instantaneous field of view (IFOV) of a detector needed to obtain this resolution, and also the "dwell time" for the sensor to advance one line of pixels. Finally, if the physical size of the detector pixels is 7 μm, what focal length telescope would be required to produce the above IFOV? Show the equations you use and your algebra.

Something 0.5 m across at a distance of 50 km occupies an angle of

$$\theta = \frac{L}{r} = \frac{0.5\,\mathrm{m}}{50\times10^{3}\,\mathrm{m}} = 1\times10^{-5}\,\mathrm{radians} = 10\,\mu\,\mathrm{rad}\ .$$

The camera advances at 1.6 km/s and the dwell time is simply the time for a single feature to move across a pixel, or equivalently, the time for the camera to advance the distance of one pixel width. Therefore

$$d = v\times t \quad \text{or} \quad t = d/v = (0.5\,\mathrm{m})/(1.6\times10^{3}\,\mathrm{m/s}) = 3.12\times10^{-4}\,\mathrm{s} = 0.312\,\mathrm{msec}.$$

Because rays through the center of the lens are undeflected, the detector pixel as seen from the lens, a distance f away from the detector, occupies this same IFOV angle θ. So

$$\theta = \frac{7\mu\mathrm{m}}{f} = \frac{7\times10^{-6}\,\mathrm{m}}{f} = 1\times10^{-5}\,\mathrm{radians} = 10\,\mu\,\mathrm{rad}$$

$$f = \frac{7\mu\mathrm{m}}{\theta} = \frac{7\times10^{-6}\,\mathrm{m}}{1\times10^{-5}\,\mathrm{radians}} = 0.7\,\mathrm{m}\ (\text{ = 700 mm in common photography units}).$$

b) (10 points) Once you've obtained your own answers, examine the LROC web site at <http://lroc.sese.asu.edu/> to see what instrument parameters they quote, and how well those agree with your estimates. You won't find all of your values there, but will find some. You may also want to examine some of their lunar images.

Under the "Learn More" tab, then the "Specs" page, they list the resolution as 0.5 meters per pixel (10 μrad IFOV) and they also list the focal length as 700 mm.