

Detecting Snow Cover on GPS Antenna

ASEN6090 Final Project

Kyle Wolma
Logan Finch
Praveen Vikram

Department of Aerospace Engineering Sciences
Colorado University
`kyle.wolma@colorado.edu`
`logan.finch@colorado.edu`
`praveen.vikram@colorado.edu`

May 04, 2012

Outline

- ▶ Goals
- ▶ Sites
- ▶ Model
- ▶ MP_1 Results
- ▶ SNR Results
- ▶ Position Results
- ▶ Conclusions

Goals

- ▶ Generate an index representative of snow cover over GPS antenna.
- ▶ Considerations for Reflections study:
 - ▶ How much of an effect will Snow cover directly over the antenna have on received signal power from lower elevation angles.

Sites

Sites for Primary Study

- ▶ P360 *
- ▶ P101 *
- ▶ AB33
- ▶ P455

** sites have a digital camera installed on site.*

Model

- ▶ Basic EM wave propagation (Plane solution to Maxwell's Equations)

$$E = E_0 e^{j(k \cdot r - \omega t)}, \quad (1)$$

Where,

$$\frac{\omega^2}{k^2} = \frac{c^2}{\epsilon}$$

However, If ϵ is complex

$$E = E_0 \exp[j(\text{Re}(k) \cdot r - \omega t)] \exp[-\text{Im}(k) \cdot r]. \quad (2)$$

Model

- ▶ Dielectric of Snow?

- ▶ Phase velocity in a medium is dependent on the frequency of the wave-front.
- ▶ As a consequence the dielectric constant of a medium is dependent on the frequency of the EM-wave.
- ▶ Phase velocity of the wave is given by

$$v = \frac{\omega}{k} = \frac{c}{n}$$

Where, n is the refractive index of the the medium

$$n = \sqrt{\epsilon}$$

- ▶ Dielectric of Snow for GPS L1 frequency?

Model - ϵ for Snow

- ▶ Snow is a mixture of Ice, Air and Water.
- ▶ From [1]
 - ▶ Consider a 2 component mixture: ice and air
 - ▶ Let their volume fractions be p_i and $p_a = (1 - p_i)$
 - ▶ let their dielectric constants be ϵ_i and ϵ_a
 - ▶ The Dielectric constant of the combination is given by,

$$\epsilon_s E_s = \epsilon_i p_i E_i + \epsilon_a p_a E_a \quad (3)$$

- ▶ Where E_s , E_i and E_a is the mean electric field strength for the EM wave under consideration in the different media.

[1] Y. Ozawa and D. Kuroiwa, "Dielectric Properties of ice, snow and supercooled water" in *Microwave propagation in Snowy districts*, no. 6, pp. 31-71, 1971

Model - ϵ for Snow

- From [2]

- The Dielectric constant of the combination is given by,

$$\epsilon_s = \epsilon'_s - j\epsilon''_s$$

Where

$$\epsilon'_s = 1 + 2\rho_d$$

$$\epsilon''_s = \epsilon'_s \times 1.59 \times 10^6 \times \frac{0.52\rho_d + 0.62\rho_d^2}{7 + 1.7\rho_d + 0.7\rho_d^2} \times (f^{-1} + 1.23 \times 10^{-6}\sqrt{f})e^{0.036T}$$

- Where,

ρ_d is relative density of dry snow

T is the temperature of snow in Celsius.

[2] M.E. Tiuri, A.H. Sihvola, E.G. Nyfors, M.T. Hallikaiken, "The complex dielectric constant of snow at microwave frequencies", *IEEE J Ocean. Eng.* OE-9 (5), pp. 377-382, 1984

Model - ϵ for Snow

- ▶ An approximate complex permittivity for dry snow for GPS frequency is $1.48 - j2.71 \times 10^{-4}$