TBL # 4: Glacier Applications for Ground Penetrating Radar (GPR)

DUE: Wednesday October 26th, 2016

Overview

Ground penetrating radar (GPR) sends a pulse of electromagnetic waves into the Earth. As GPR signals propagate through the Earth, they reflect, transmit and refract at interfaces. The propagation of the GPR signal depends on the frequencies contained in the source wavelet and the electromagnetic properties of the Earth; most importantly the dielectric permittivity. Because GPR uses high frequencies, it provides high resolution images of subsurface structures.

As professionals, you will need to evaluate the decisions made and conclusions drawn in various settings. The case histories you will be using for this exercise are used as promotional material. The questions are posed within the 7 step framework. Please provide insightful but brief answers to the following questions.

Instructions

Answer the following questions within the context of the 7 step framework. Your answers should be brief. Point form can be used where appropriate. In Appendix: GPR instrument, we provided specifications of the GPR instrument used in the case study.

Individual exercise:

- Read the Glacier Girl article and answer the following questions before the in-class TBL. **There are no articles needed for the in-class TBL.**

Resources

- GPG Geophysical Surveys: Ground Penetrating Radar
- Glacier Girl
- GPR Movie: GPR Movie (available at this link)

Wave approach

GPR signals propagate through the Earth as wavefronts. However, we can use ray paths to represent the different ways in which GPR signals can travel from the transmitter to the receiver. Below we see the location of a wavefront at three different times and several ray paths.

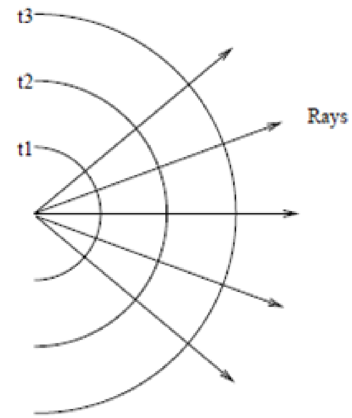

Figure 1: Conceptual diagram of wavefront and ray.

Q1. Watch the GPR Movie and look at the various wavefronts. Note that you can step through frame-by-frame using the arrows at the bottom (second and sixth buttons), or slow the frame rate using the minus-sign button on the left. In the GPR movie, Tx indicates the source location, and Rx with the red dots indicate receiver locations. No specific distances are provided and none are needed to answer the following questions.

a. Consider the screen shot at 96ns shown below: Label the following wavefronts: (1) Direct air wave; (2) Direct ground wave

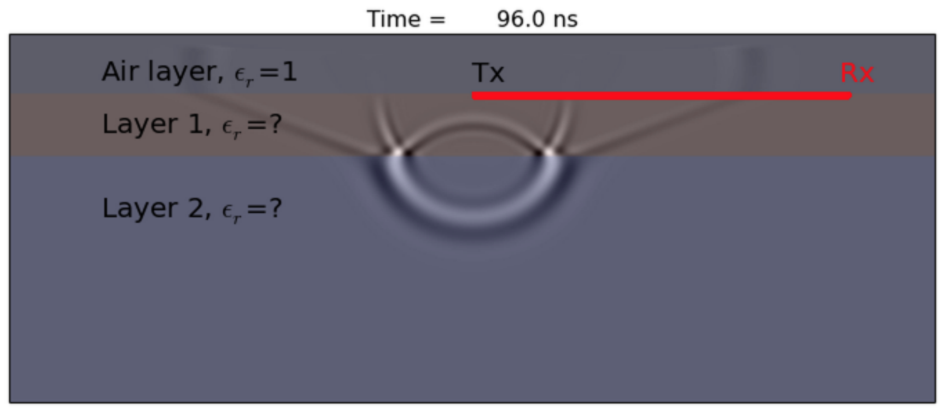

Figure 2: At 96 ns

b. Determine the velocity of layer 1 and use that to obtain the relative permittivity of layer 1. You can start by using the air wave velocity and travel time to get the length of the red line.

c. On the same screen shot (Figure 2) label the wavefronts that correspond to the (1) reflected and (2) transmitted waves.

Q2. Consider the screen shot at 144ns shown below.

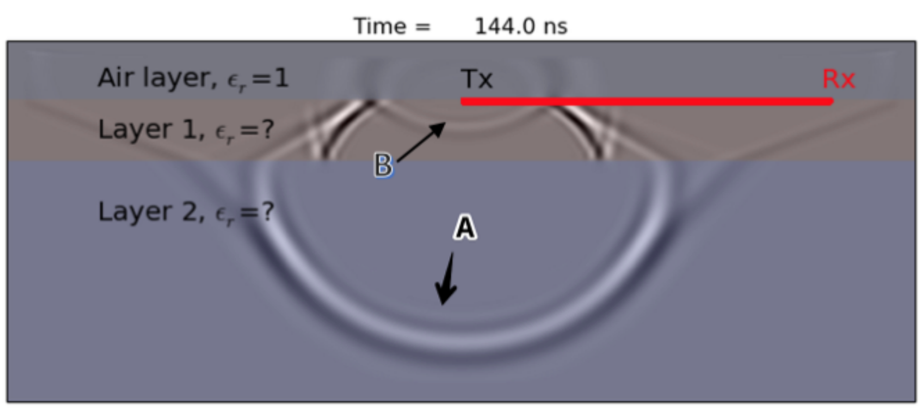

Figure 3: At 144 ns

a. What is the physical understanding of the wavefront labeled A?

b. What is the physical understanding of the wavefront labeled B?

c. Is the dielectric constant of the second layer in the earth less than, or greater than, the dielectric constant of the first layer? Justify your answer.

Case Study: Glacier Girl

Setup

Q3. What motivated this study?

Q4. What background information was used to select a survey area?

Physical Properties

Q5. Which physical properties were diagnostic for this case study?

Geophysical Survey

Q6. Which instrument is selected for this case study and what was the center frequency?

Q7. What is the stated vertical resolution of this system? Calculate the theoretical vertical resolution using the quarter-wavelength formula and the standard physical properties for ice. How do these two values compare?

Data

Unlike seismic reflection surveys, which have multiple receivers for each source, GPR surveys usually employ a single receiver antenna per each source antenna. Depending on the GPR system, it is possible to perform both common midpoint (CMP) and common offset surveys.

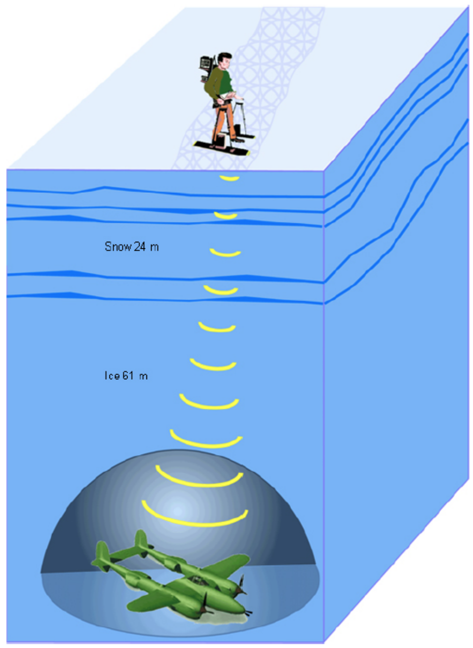

Figure 4: Geologic model for Case Study 2.

Q8. Using Figure 4, sketch a cross-section showing the survey geometry, snow-ice interface and airplane. Sketch 3 source-receiver pairs for a common **offset** GPR gather. Include ray paths corresponding to reflections events you expect to see in the data.

Processing and Interpretation

Q9. The raw data were collected using a common offset configuration. Given the scale of the problem and the offset, the configuration can effectively be considered a zero offset. The processed data shows a strong reflector at 80 m which has a slightly hyperbolic shape.

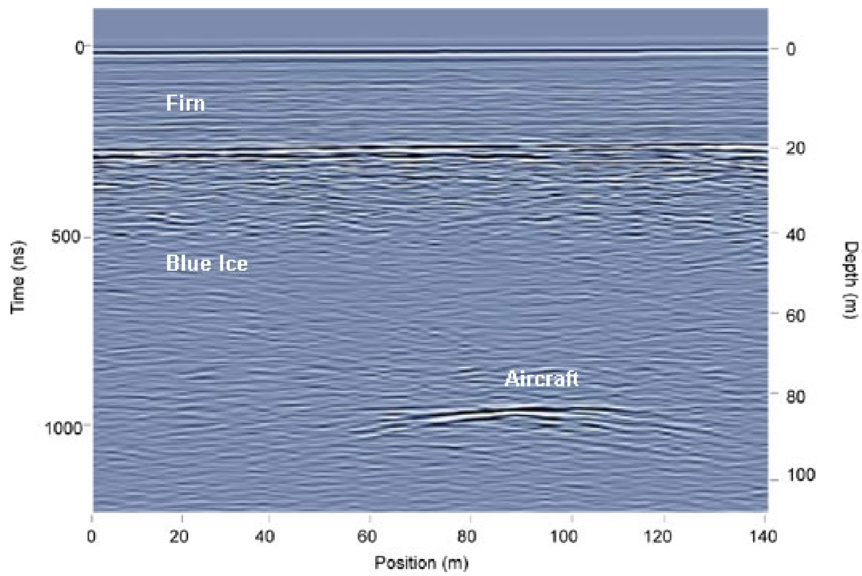

Figure 5: GPR section of the second case study.

a. Note that the data has a vertical depth axis. However, we know that individual traces record the travel time. What is one way you could convert the travel times to depth? (2 steps).

b. Officially, we have no information on how the authors performed the depth conversion. Let's assume they chose a constant velocity. (i) If so, use figure 5 to estimate the velocity they used. (ii) For this value, calculate the corresponding relative permittivity (iii) Is this value close to the typical relative permittivity of ice?

c. There are measured signals at roughly t = 0 ns. What do these signals correspond to?

d. In theory, we should have two direct arrival signals. What are they called and where does each one propagate?

e. Based on the above radargram, can we distinguish the signals from each of the direct waves? Why/why not?

Synthesis

Q10. In the section: 'GPR contribution to Solution', the authors said "Glaciers and ice sheets are excellent environments for GPR".Do you agree with this statement? Support your answer by considering physical properties, probing distance and resolution.

Appendix: GPR instrument

50MHz pulseEKKO

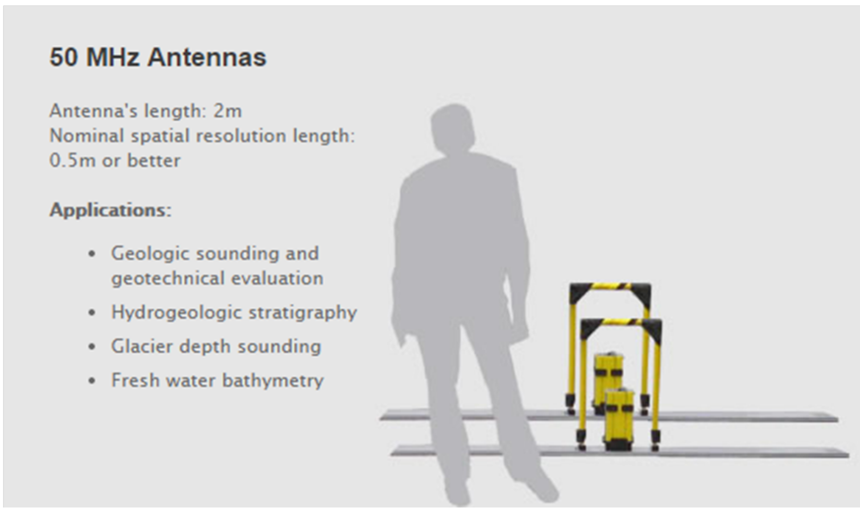

Figure 6: Sensors and Software 50MHz pulseEKKO description.