Team TBL #4: Understanding GPR signals and Survey Design

DUE: October 30, 2015

Overview

Ground penetrating radar (GPR) sends a pulse of radiowaves 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 and electrical conductivity. Because of the high frequencies used, GPR has high resolution, enabling us to image various buried objects such as pipes, historical remains, and geologic interfaces.

In your individual TBL you looked at GPR waves in a layered earth and also the application of a GPR survey to find a buried airplane. In the Team TBL you will: (a) revisit the movie and answer questions collectively (b) generate your own GPR survey to find some buried utilities (c) look at aspects of resolution and probing distance.

Instructions

Team exercise:

- Discuss the movie amongst yourselves
- As a team, answer the following questions
- You will hand this in at the end of the class

Resources

- GPG - Ground Penetrating Radar
- GPR Movie
- AttenuationApp Ipython Notebook for EM wave attenuation

Part I: GPR Movie

Q1. Watch the GPR Movie and look for the waves. 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 locations are represented by the red line. 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: (A) Direct air wave; (B) Direct ground wave; (C) Reflected wave off the lower interface.

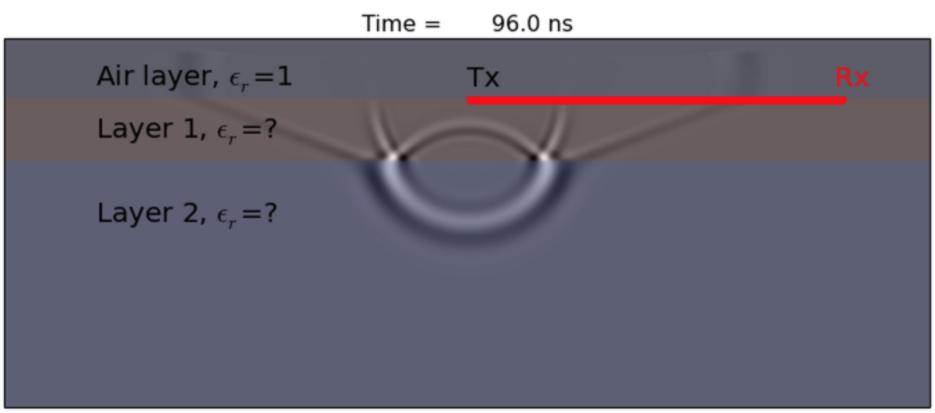

Figure 1: At 96 ns

b. Examine the thickness of the wavefronts in layer 1 and layer 2. (i) Is the spatial length of the wavelet signal larger in layer 1 or layer 2? (ii) Based on the information provided, rank the propagation velocity of all three mediums from highest to lowest.

c. The expression for the horizontal resolution of objects is $L = \sqrt{\frac{vd}{4f}}$. Based on the variables in this equation, provide **two** reasons why it would be harder to differentiate two nearby object in layer 2 as opposed to layer 1.

Part II: Survey design

Setup

In order to maintain a water service pipe network in town, pipes under roads must be periodically dug up and replaced. Unfortunately, utility maps for the area are old and out of date. Knowing the precise location and depth of each pipe is important, as buried gas lines and electrical wires can pose as serious hazards.

Fortunately, you have access to several GPR systems. The central operating frequencies for these systems are 25 MHz, 100 MHz and 1000 MHz, respectively. Each GPR system is contained within a single box. As a result, each system uses a **zero offset** configuration. Your objective is to design surveys which 1) have a sufficient probing distance and 2) provide sufficient resolution for the objects you want to find. These objects are:

(a) Utilities such as main domestic gas pipes and/or electrical utility wires. These objects are typically buried between 20cm and 50cm and have diameters of 5 cm or more.

(b) A water pipe. The top of the pipe is known to be between 1 and 2 metres below the surface. We also know the pipe has a 1 metre diameter.

Some additional information:

(a) The pipes and cables run parallel to the road.

(b) The conductivity of the earth is uniform and has a value $\sigma = 31.6$ mS/m; note $\log(\sigma) = -1.5$.

(c) The background Earth material is compact and moist. A good estimate for its relative permittivity is $\varepsilon_r = 9$.

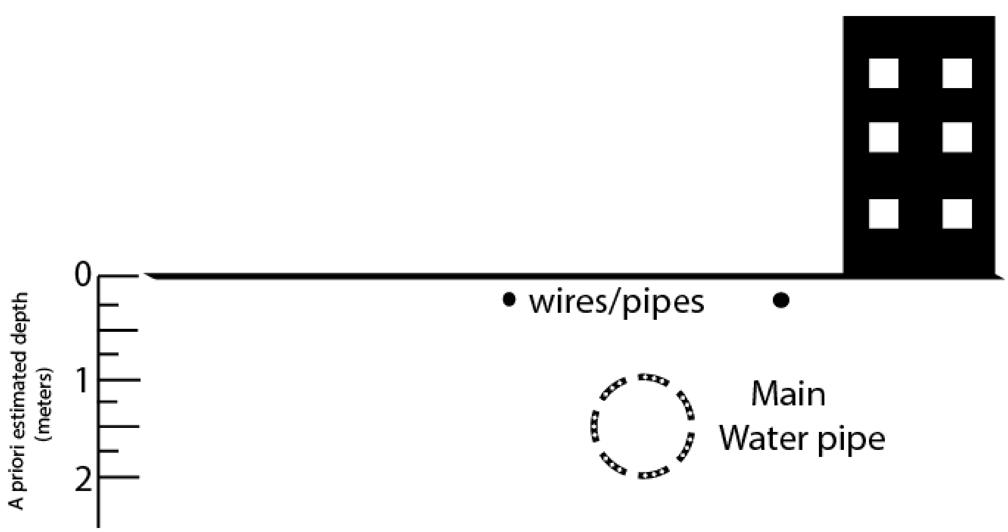

Figure 2: Sketch of the area to survey

Q2. If you forgot to shield the transmitter and receiver, what sources of noise may contaminate your data? (name two)

Q3. Given the pipe orientation, how would you orientate your acquisitions line?

Sketch

Q4. In order to consider the expected GPR signature from the pipe, we consider the model below.

a. First, sketch the reflected ray paths for the pipe model given below at figure 3.

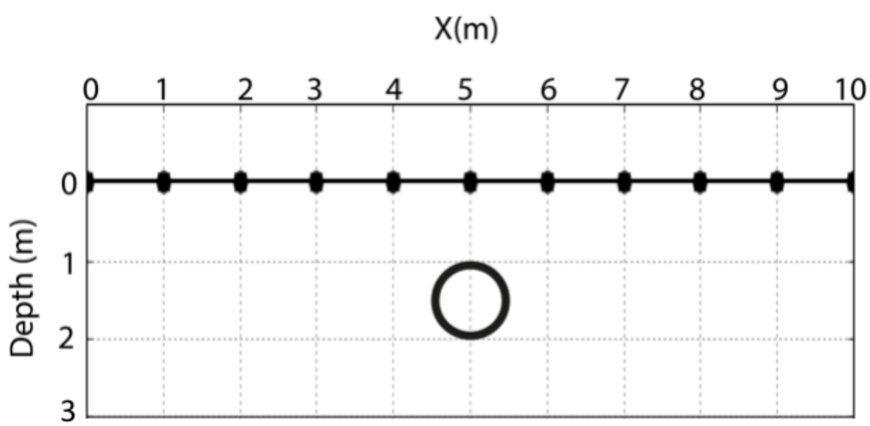

Figure 3: Ray paths for the pipe model for a zero-offset transmitter and receiver

b. Based on your a-priori knowledge, (i) what is the propagation velocity in the Earth? (ii) What is the minimum travel time? (iii) Based on the ray paths you drew, sketch the arrival time of those rays at receiver locations on figure 4. Make sure the slopes on the outsides of the signature correspond to the reciprocal of the propagation velocity.

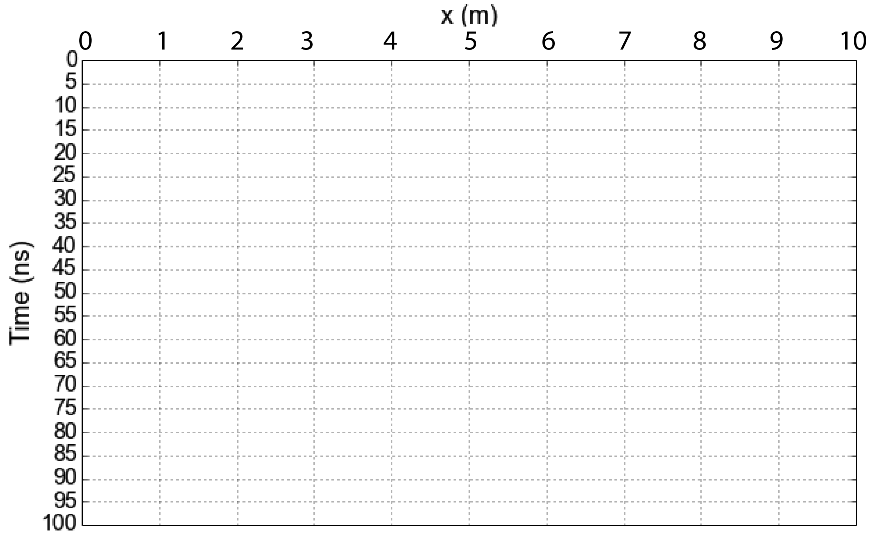

Figure 4: Arrival times for the pipe model

Q5. At x = 10m, the survey line ends because we hit the wall and foundation of a building. The wall and foundation are perpendicular to the survey line. There are two reflected signals from the building. What are they? Sketch the radargram signature of both these signals on the radargram above.

Q6. Provide a mathematical expression for the slope of each reflected signal in the radargram.

Properties

Q7. Here, we are going to examing the effects of conductivity on our ability to detect buried objects with GPR. We will use the AttenuationApp to answer the following questions. Assume the relative permittivity of the Earth is $\varepsilon_r = 9$.

- The probing distance is roughly equal to 3 skin depths.
- A good estimate for the horizontal resolution is $L = \sqrt{\frac{vd}{4f}}$.

- Note: $\log(0.0316 \text{ S/m}) = -1.5$

a. Using a transmitting frequency of 25 MHz, if the background conductivity is 0.0316 S/m (note that $\log(0.0316) = -1.5$S/m) and the wires are buried 20cm below the surface, are the wires within the probing distance?

b. At what conductivity can you no longer see the wires?

c. If the wires are 20cm apart, can they be resolved when the background conductivity is $\log(\sigma) = -1.5$?

d. Can they be resolved at 100 MHz? 1000 MHz?

e. At 1000 MHz, is the penetration depth deep enough to see the wires?

f. If the conductivity is $\log(\sigma) = -0.5$, what frequency of radar system would you use to observe and resolve the two wires.

g. If the water pipe is 2m below the surface, and the background conductivity is $\log(\sigma) = -1.5$, what frequency of radar do you need to see it?