



RADAN Data Processing Training Course Outline and Info Packet

Where is class held?

Class is held at GSSI Headquarters at 12 Industrial Way, Salem, NH.

When are the classes?

The class schedule is on our website at <http://www.geophysical.com/training.htm>.

Class size is limited to 8 students, so reserve a spot early. You can reserve a spot simply by contacting the Training Manager, Dan Welch at 603-893-1109 or welchd@geophysical.com.

What are the class times?

Classes run three days from 9AM to 4:00PM with approximately 1 hour for lunch. Five-minute breaks are given every hour.

What does it cost?

Class tuition is \$800 per student. If you purchased a complete StructureScan Optical system, it came with 2 free class credits. You can either send two people to one class or one person to two different classes.

Where should I stay?

There are a number of hotel options within a 10-15 minute drive of GSSI. A listing with phone numbers is included in this packet.

How far is GSSI from the airport?

Roughly 45 miles from Boston's Logan International Airport, and roughly 30 miles from Manchester (NH) Airport. Boston is currently in the middle of the 'Big Dig' construction project and traffic to and from the airport is usually very heavy at all times during the day. Manchester is a much easier airport to travel through.

Do I need to rent a car?

Yes. There is no public transportation from the airport to Salem, and no public transport around town. GSSI cannot pick you up from the airport.

What should I bring?

You will get as much out of the class as you put into it so, be prepared to take notes. A portion of the course requires some intensive computer work. You should be familiar with working in a Microsoft Windows environment. You should be able to:

1. Create and rename a folder in Windows.
2. Move files around your computer by 'dragging and dropping' or cutting and pasting. The instructor will not teach this, and it is your responsibility to acquire this knowledge before coming. The standard tutorials that come with Windows should be enough.

You may videotape or record the training if you wish. If you want to bring your personal equipment to work with, that is fine but not required. Students will be evaluated by class participation and oral examinations.

If possible, bring a laptop computer with RADAN loaded on it. GSSI also has training computers available for you to use.

What if I need to cancel/reschedule?

Just contact us and let us know 48 business hours before the class. You will not be billed for the class. Failure to show without prior cancellation may result in a penalty.

Should I plan to stay and see the sights?

Absolutely. In addition to being one of the finest sports towns in the country, Boston has a huge variety of historical and cultural activities including: professional sports, Revolutionary War sites, a world class art museum, aquarium, and many great restaurants. Very fine hiking and skiing are also a short drive away.

Hotels Near GSSI

Please contact individual hotels for latest rate

Holiday Inn

1 Keewaydin Drive
Salem, NH 03079
Tel: 603.893.5511
Fax: 603.894.6728

Website: www.holiday-inn.com

Restaurant and Lounge in hotel

LaQuinta Inn & Suites

8 Keewaydin Drive
Salem, NH 03079
Tel: 603.893.4722
Fax: 603.893.2898

Website: www.lq.com

Continental breakfast served at hotel

Red Roof Inn

109 South Broadway
Salem, NH 03079
Tel: 603.898.6422
Fax: 603.898.6497

Website: www.redroof.com

No Restaurant or Lounge in Hotel

Wyndham Hotel

123 Old River Road
Andover, MA 01810
Tel: 978.975.3600
Fax: 978.975.2664

Website: www.wyndham.com

Restaurant and Lounge in hotel

Park View Inn

109 South Broadway (RT 28)
Salem, NH 03079
Tel: 603-898-5632
Fax: 603-894-6579

No Restaurant or Lounge in Hotel

The Red Roof, LaQuinta and Holiday Inn are clustered together and are the closest hotels to GSSI. Drive time is less than 5 minutes.

Directions to Hotels from Logan Airport (Boston, Mass) or Manchester Airport (Manchester, NH)

From Boston's Logan Airport To Motels

1. When exiting the airport follow the signs to I 93 north.
2. Take I 93 North to New Hampshire. It takes approximately 30 minutes to reach the New Hampshire state line.

For the **Park View**:

1. Take Exit 1 (Rockingham Park) off I 93, you will be heading east.
2. Continue straight for the exit road, you will pass the Rockingham Mall, and Rockingham Race Track on your left.
3. Go straight through the first stop light at the second stop light (Route 28) turn left. You will be heading North on Rte. 28. Within about ¼ mile (400m) the Park View will be on your right. The motel is set back from the road near a plaza so it is difficult to see, but there is a prominent sign at roadside.

For the **Holiday Inn, LaQuinta, and Red Roof Inn**:

1. Take Exit 2 off of I 93.
2. **Red Roof Inn**: Turn right at the bottom of the exit ramp. The Red Roof Inn is on the right side of the road about ¼ mile (400m) down the road.
3. **Holiday Inn**: Turn left at the bottom of the exit ramp. Go under I93 and take the first left turn (about 100 yards (100m) from I 93). Go approximately ¼ mile (400m) and the Holiday Inn will be on the left.

From Manchester Airport To Motels

1. When exiting the airport follow the signs to I 293.
2. Take Brown Avenue north for about 4 minutes to the entrance ramp for I 293 South (there is a stop light here).
3. Turn right onto the entrance ramp for I 293 south (the sign will say I 293 to I 93)
4. Take I 293 for about 3 minutes until the highway divides. Take the right branch to I 93 South.
5. Head south on I 93 for about 20 minutes until Exit 2 or Exit 1.

For the **Park View**:

1. Take Exit 1 (Rockingham Park) off of I 93, you will be heading east. Follow directions for the Park View described above.

For the **Holiday Inn, LaQuinta, and Red Roof Inn**:

1. Take Exit 2 off of I 93. Directions same as previously described.

Directions from Hotels to Geophysical Survey Systems, Inc.

From the Park View:

1. Take Rte. 28 north until the junction with Rte. 97.
2. Take a left onto Rte. 97 West. Follow 97 West for approximately 1 mile.
3. Turn right at traffic light onto Manor Parkway.
4. Turn left onto Industrial Way. GSSI is on top of the hill on the right hand side just after the IR Hussman Company.

From the Holiday Inn, Red Rood, and LaQuinta:

1. Take a left from Keewaydin Drive onto Rte. 97 (Pelham Road) west.
2. Turn right at traffic light onto Manor Parkway.
3. Turn left onto Industrial Way. GSSI is on top of the hill on the right hand side just after the IR Hussman Company.

Class Schedule

	Morning	Afternoon
Day 1	<p style="text-align: center;">RADAN Introduction</p> <p>An introduction to GPR and RADAN method and theory. Topics covered include: Structure of a GPR record, RADAN program structure and software setup. Review of key GPR concepts.</p>	<p style="text-align: center;">Data Processing I</p> <p>Adjusting the horizontal scale, horizontal filtering, vertical filtering.</p>
Day 2	<p style="text-align: center;">Data Processing II</p> <p>A review of the previous afternoon's learned skills.</p> <p>Range gain, migration, F-K filtering, deconvolution..</p>	<p style="text-align: center;">Creating 3D files</p> <p>Understanding the structure of a 3D dataset. Creating a 3D file out of multiple 2D files. Specialized 3D processing and imaging.</p>
Day 3	<p style="text-align: center;">Interactive Interpretation</p> <p>Understanding the functionality of the Interactive Interpretation portion of RADAN. Picking targets and exporting to 3rd party software..</p>	<p style="text-align: center;">Review and student projects.</p>

Ground-Penetrating Radar 101: Theory and Practice

Introduction

This document is designed as a basic introduction to some of the key concepts in the basic theory of operation of ground-penetrating radar (GPR). An understanding of the concepts discussed here will help make your training experience much more worthwhile and enable the trainer to spend more time preparing you for actual field situations. You are encouraged to read through this *prior* to your training class. The instructor will explain all of these concepts in much greater depth in the class, but a passing familiarity with the terms will help you. If you have any additional questions, or would like more information about a particular concept discussed here, please feel free to call Geophysical Survey Systems, Inc. at (603) 893-1109.

Equipment

A GPR system is made up of three main components: the control unit, antenna, and power supply (Figure 1).

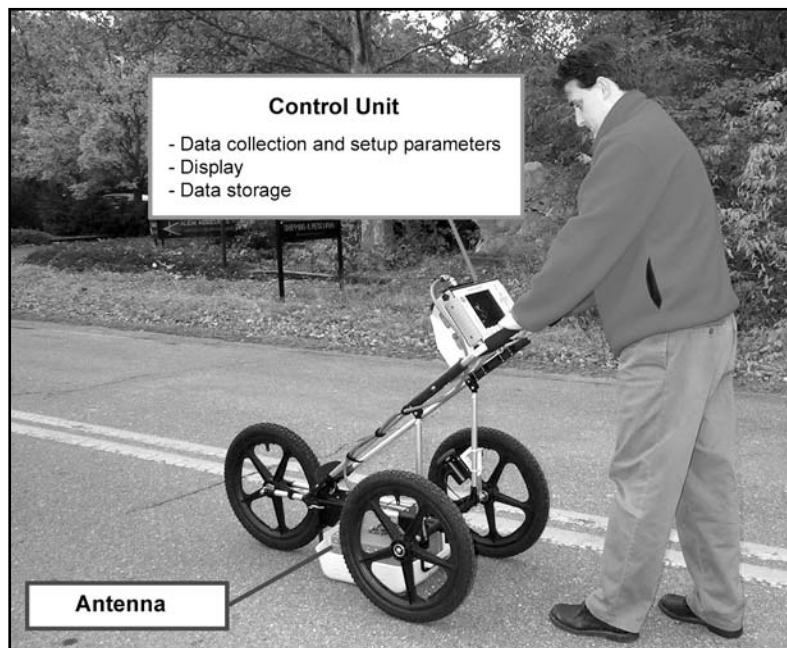


Figure 1: Complete GPR system

Geophysical Survey Systems GPR equipment can be run with a variety of power supplies ranging from small rechargeable battery packs, to vehicle batteries, and normal 110-volt current. Connectors and adapters are available for each power source type. The unit in the photo above can run from a small internal rechargeable battery or external power.

The control unit contains electronics that produce and regulate the pulse of radar energy that the antenna sends into the ground. It also has a built in computer and hard disk to record and store data for examination after fieldwork. Some systems, such as the GSSI SIR-20, are controlled by an attached Windows laptop computer with pre-loaded control software. This system allows data processing and interpretation without having to download radar files into another computer.

The antenna receives the electrical pulse produced by the control unit, amplifies it, and transmits it into the ground or other medium at a particular frequency. Antenna frequency is a major factor in depth penetration. The higher the frequency of the antenna, the shallower into the ground it will penetrate. A higher frequency antenna will also ‘see’ smaller targets. Antenna choice is one of the most important factors in survey design. Table 1 shows antenna frequency, approximate depth penetration, and appropriate application.

Depth Range (Approximate)	Primary Antenna Choice	Secondary Antenna Choice	Appropriate Application
0-1.5 ft 0-0.5 m	1500 MHz	900 MHz	Structural Concrete, Roadways, Bridgedecks
0-3 ft 0-1 m	900 MHz	400 MHz	Concrete, Shallow soils, Archaeology
0-12 ft 0-3 m	400 MHz	200 MHz	Shallow Geology, Utilities, UST's, Archaeology
0-25 ft 0-9 m	200 MHz	100 MHz	Geology, Environmental, Utility, Archaeology
0-90 ft 0-30 m	100 MHz	Sub-Echo 40	Geologic Profiling
Greater than 90 ft, or 30 m	MLF (80, 40, 32, 20, 16 MHz)		Geologic Profiling

Table 1: Choosing the Proper Antenna

The GPR Method: Theory of Operation

GPR works by sending a pulse of energy into a material and recording the strength and the time required for the return of any reflected signal. A series of pulses over a single area make up what is called a scan, or sometimes a trace. Reflections are produced whenever the energy pulse enters into a material with different electrical conduction properties (dielectric permittivity) from the material it left. The strength, or amplitude of the reflection is determined by the contrast in the dielectric constants of the two materials. This means that a pulse which moves from dry sand (diel of 5) to wet sand (diel of 30) will produce a very strong, brilliantly visible reflection, while one moving from dry sand (5) to limestone (7) will produce a very weak reflections.

While some of the energy is reflected back to the antenna, energy also keeps traveling through the material until it either dissipates (attenuates) or the GPR control unit has closed its time window (Figure 2). The rate of signal attenuation varies widely and is dependant on the

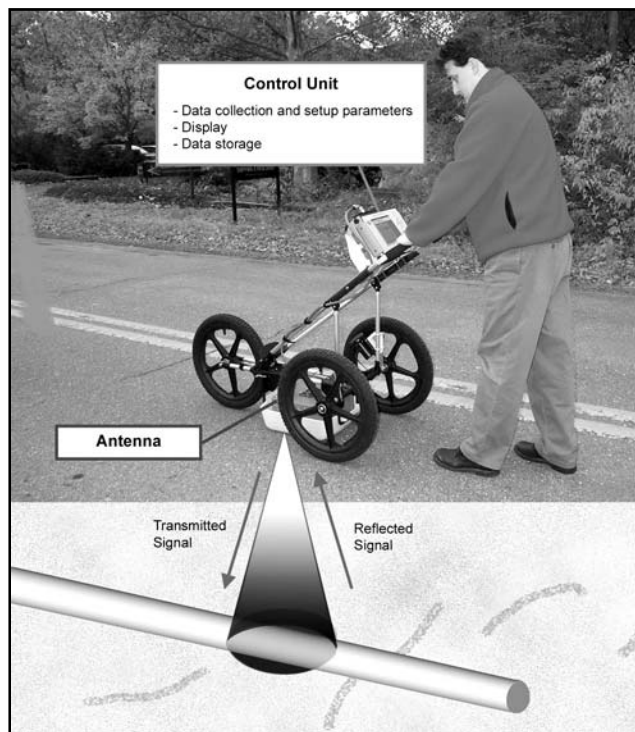


Figure 2.

dielectric properties of the material through which the pulse is passing. Another concern is conductivity. Materials which are highly conductive and thus attenuate (absorb) the signal rapidly. If the signal is absorbed, then it is not allowed to penetrate deeper into a material. Water saturation dramatically raises the dielectric (and sometimes the conductivity) of a material, so a survey area should be carefully inspected for signs of water penetration. Radar surveys should never be conducted through standing water, no matter how shallow. Depth penetration through a material with a high dielectric will not be very good. Metals are considered to be a complete reflector, and do not allow any amount of signal to pass through. Materials beneath a metal sheet, fine metal mesh, or pan decking will not be visible. It is essential to correctly estimate the dielectric constant of a material in order to get accurate depth calculations to features. In utility and concrete inspection work, this is commonly done by drilling or chipping to a known object

such as a piece of rebar, measuring the depth, and calibrating that depth to the radar record. The depth accuracy of radar is extremely good if this calibration is performed. If there is a suspicion of changing conditions in the subsurface (different material, water infiltration), another depth calibration for that area should be done. Generally speaking, the more depth calibrations that are performed, the more accurate the depth estimate. If chipping or drilling is not possible, or if the survey takes place out of doors on a natural ground surface, the dielectric must be estimated. A chart of the dielectric constants of some common materials is included at the back of this booklet for reference.

Radar energy is emitted from the antenna not in a straight line, but a cone (Figure 3). The two-way travel time for energy at the leading edge of the cone is longer than for energy directly beneath the antenna. This is because that leading edge of the cone

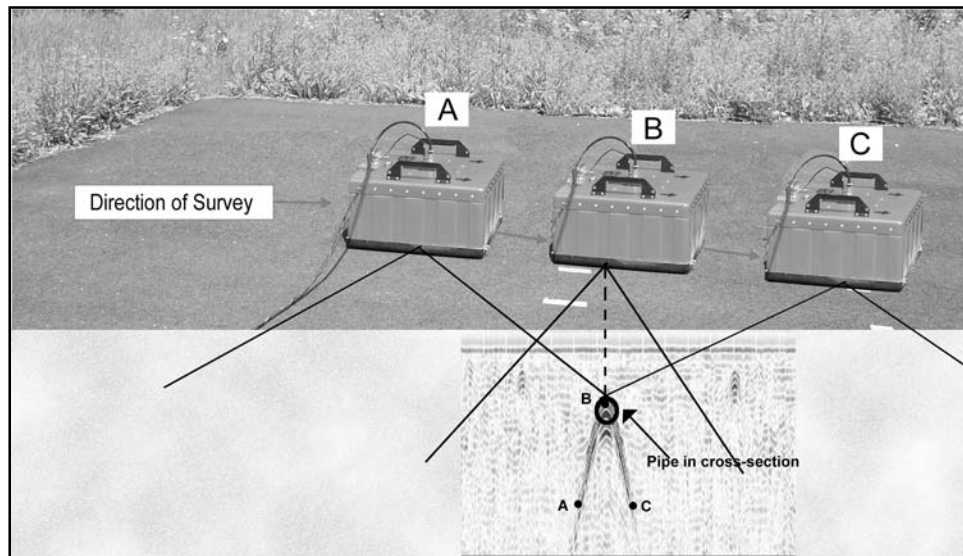


Figure 3: Hyperbola creation.

represents the hypotenuse of a right triangle. It is a longer distance than when the antenna is directly over the target. Because it takes longer for that energy to be received, it is recorded farther down in the profile. As the antenna is moved over a target, the distance between them decreases until the antenna is over the target, and increases as the antenna is moved away. It is for this reason that a single target will appear in a data as a hyperbola, or inverted “U.” The target is actually at the peak amplitude of the positive wavelet (Figure 4). A mathematical function called *migration* may be performed during the data processing stage to remove the tails of the hyperbola and produce a more accurate assessment of the target location.

A reflection wave commonly has a positive and a negative wavelet. This is why hyperbolas look striped. If radar energy moves into air (dielectric of 1) from a higher dielectric medium like concrete, the signal will undergo what is called a phase reversal. A normal reflection will exhibit first a positive peak (white band) and then a negative peak (black band), while a phase-shifted signal will show a negative (black) then positive (white) peak. If energy penetrates a thin slab and continues into the air behind it, then a phase shift may indicate the back of the slab. Additionally, voids and air-filled PVC, if they are large enough, may show up as phase-shifted reflections. In some cases however, a phase shift may be falsely produced by background noise

or the system's internal filters. It is therefore inadvisable to consider a phase shift alone to be indicative of a void or PVC piping.

Data are collected in parallel transects and then placed together in their appropriate locations for computer processing in a specialized software program such as GSSI's RADAN. The computer then produces a horizontal surface at a particular depth in the record. This is referred to as a depth slice. A depth slice allows an operator to interpret a planview of the survey area.

Survey Considerations

Ground-penetrating radar, like all geophysical techniques, is most effective when as large an area as possible is surveyed. The reason for this is that effective interpretation depends on seeing contrasts within the data. Furthermore, features at the edge of the survey area may not be seen as clearly, and it is preferable to take a slightly longer time to complete the survey, then to make a costly, potentially dangerous mistake because of an inadequate survey area. If there is to be a delay between survey and any drilling or cutting, then some method of relocating the survey area and mapped features must be devised. Survey areas can be marked on the floor in permanent marker, or the survey area's location in reference to some immobile object such as drill hole or a column should be mapped.

Example: A fiber optic cable is to be laid into a warehouse floor. The slab contains 8-inch on center rebar mesh and live power conduits in PVC laid on top of the mesh. The trench is to be 8 inches wide and dug to the top of the mesh. The client wants the conduit laid on top of the mesh, so accurate depth calculation to top of mesh is essential. Multiple drill cores to mesh are permitted for depth calibration. While it is possible to survey only the area that will be directly impacted, a much more effective technique would be to survey an additional 12 inches to the sides of the trench. This will help in the identification of targets at the edge of the trench. Cores should be taken down to the mesh all along the impact area.

GPR functions by transmitting and receiving electromagnetic energy at a particular frequency. Cellular phones, two-way radios, and pagers also transmit EM energy and will interfere with a GPR survey. If you must have them on, it is absolutely essential to keep these devices at least 25-30 feet away from the antenna.

Data Processing

Many situations will require the operator only to note the location of a target so that it can be avoided. For these clients, it may only be necessary to use a simple linescan format and mark the approximate area on the survey surface. Other clients may require detailed subsurface maps and depth to features. These situations will require the operator to use GSSI software to apply different mathematical functions to the data to remove background interference, migrate hyperbolas, and calculate accurate depth. With some GSSI systems, such as the StructureScan concrete analysis system, this is automated. Other situations may require a greater understanding of radar processing techniques, and the operator may wish to contact GSSI for additional software training after consulting the RADAN manual.