GPR and its Application

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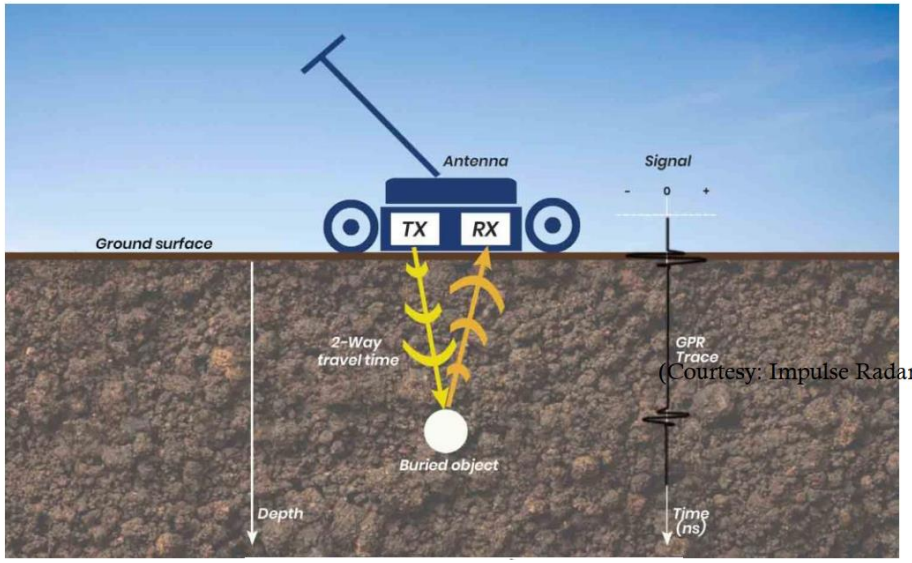
What is GPR technology?

GPR- Ground Penetrating Radar

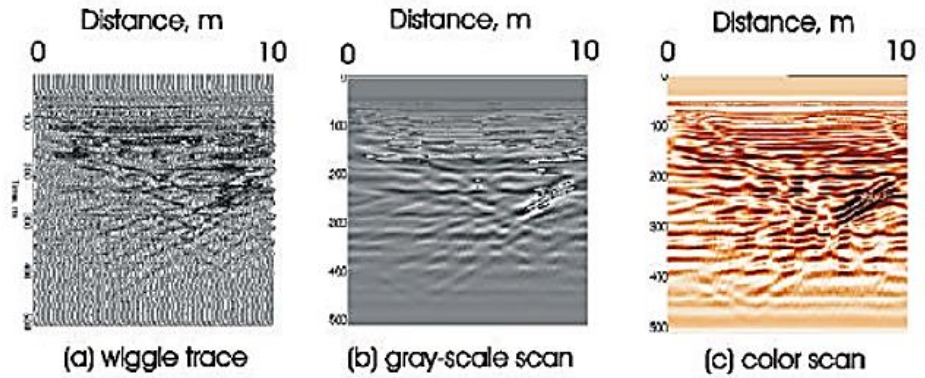
1. High resolution EM technique designed for investigating shallow sub-surfaces (e.g. earth, building materials, roads and bridges)
2. It is time-dependent geophysical technique that can provide 3D pseudo image of the subsurface as well as accurate depth estimates of many common objects in non-invasive way (e.g. pipes)
3. GPR has two advantages over most other non-invasive geophysical techniques:
   GPR provides a 3 dimensional pseudo-image that can easily be converted to depths that are accurate down to a few centimeters
   GPR responds to both metallic and non-metallic objects.
4. Material properties of buried objects can be analyzed via GPR + AI methods

GPR scans

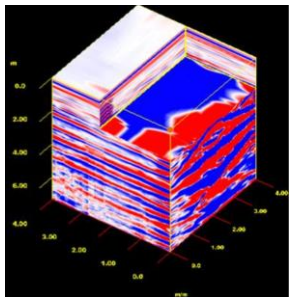


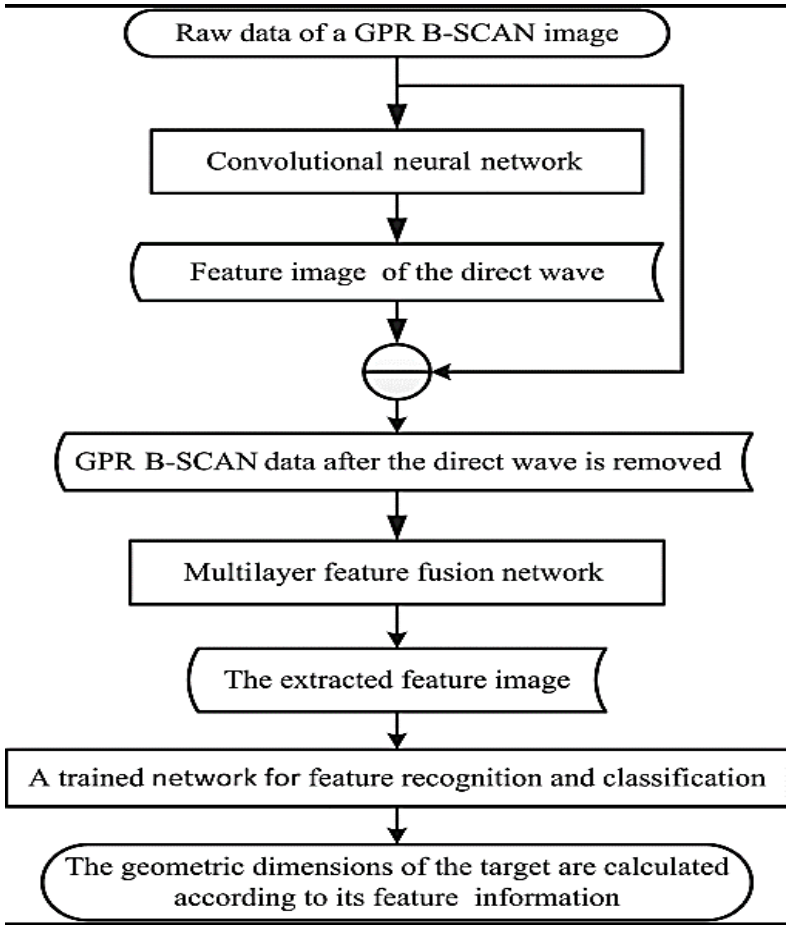
(Courtesy: Impulse Radar)

GPR traces are not directly human readable, so AI and image processing methods are required.



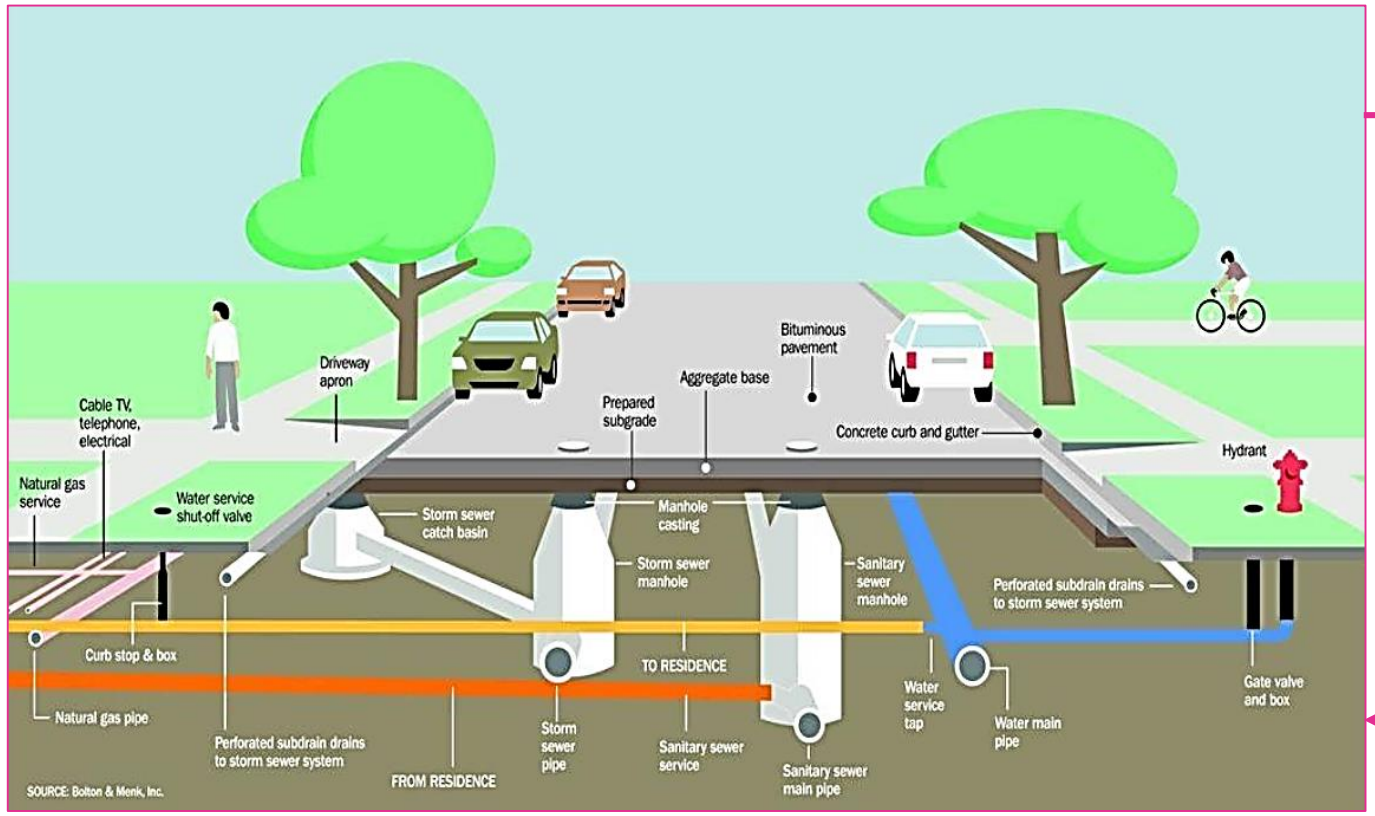
GPR 3D Display



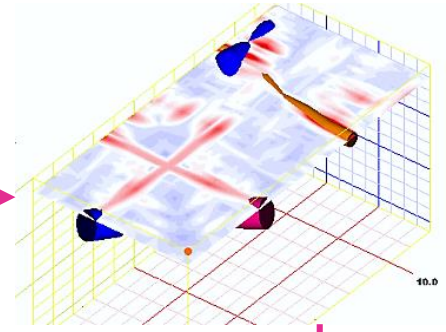


GPR for utility mapping

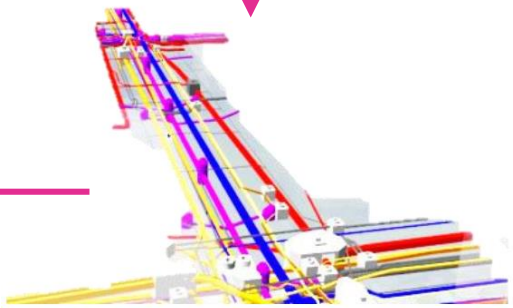
- GPR is safe for use in public places. It detects metals, plastics, PVC, voids, ground water, natural materials in non-invasive way



GPR scan



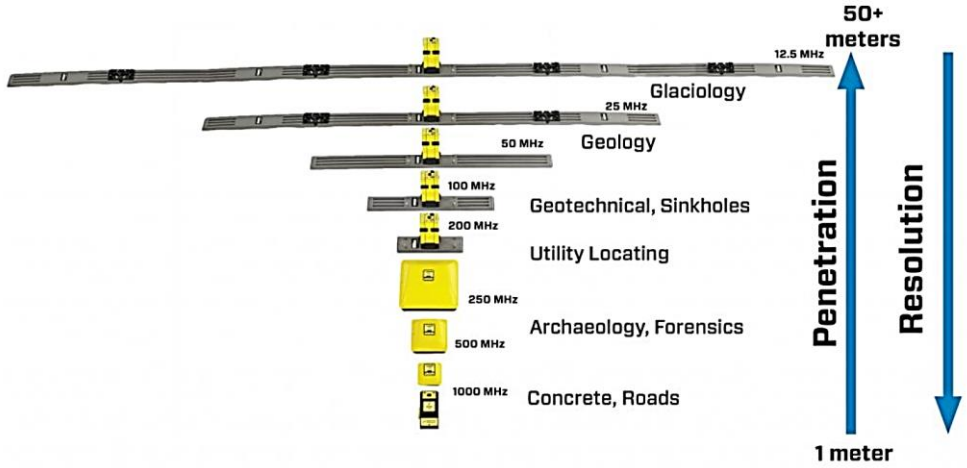
AI modelling



Blueprint & Data visualization

Compact setup to trace public roads

- Concrete road analysis needs 1000MHz frequency waves which intern offers compact antenna design. So the GPR setup will be compact and will not cause public inconvenience while municipal road tracing.
- Scans are of 4 to 5m deep underground analysis across roads with high resolution GPR images
- Data acquisition is quick and can cover large site area
- Frequencies can be regulated to deliver a range of resolution & penetration depths
- Data collected can be used immediately or stored for later projects
- Land structures, lawns, underground materials remain undisturbed.
- Less expensive than other underground survey methods



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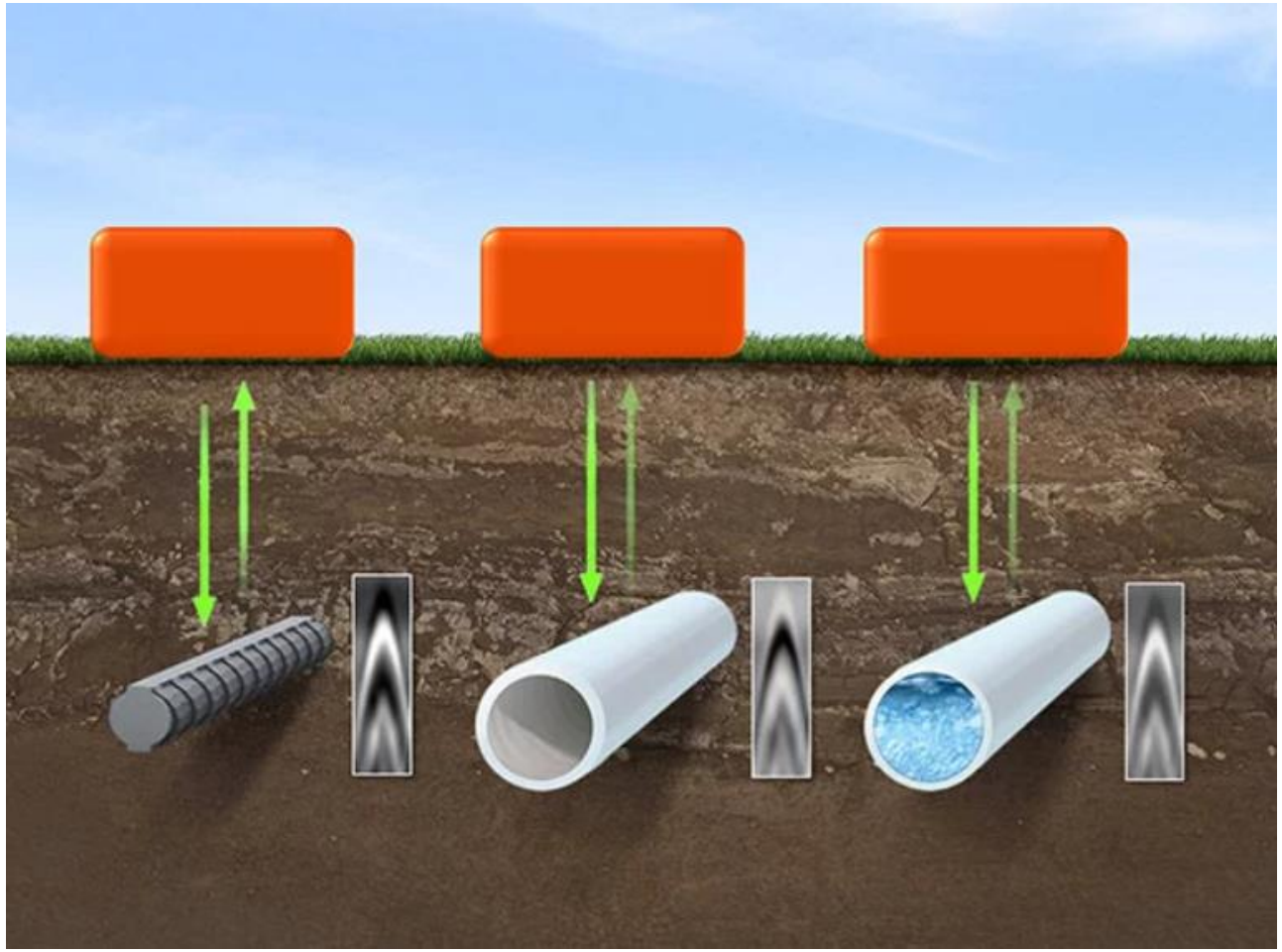
Principles of GPR

- GPR uses the same fundamental physical principles as conventional radar.
- It uses radio waves to map structures and features buries in the ground/man-made structures.
- Radar techniques principally detect back-scatterd energy from a target.
- Uses high freq radio signal that is transmitted by the antenna and travels downwards until it hits object that has diff. electrical properties from the surrounding medium then it get scattered from the object and received by the Rx. antenna



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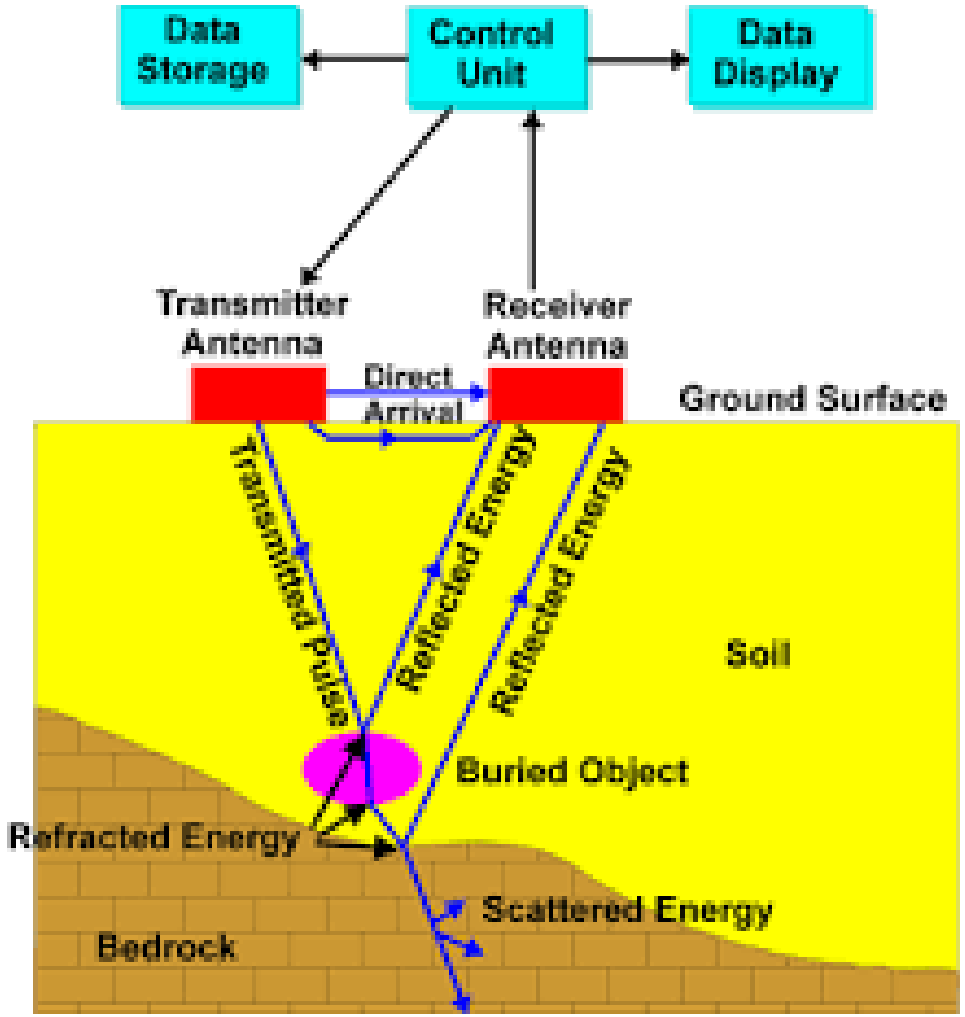
- The computer measures the time taken for a pulse to travel from the target which indicated its depth and location.
- Reflected signals are interpreted by the system and displayed on the unit's LCD panel in form of cross-sectional profile.
- If the wave hits a buried object then part of waves energy is reflected back to surface and some of its energy continues to travel downwards.
- Wave that is reflected back to the surface is captured by a receive antenna and recorded on digital storage device.
- This method measures the travel time of electromagnetic impulses in subsurface material.
- Antenna is able to detect and measure the depth of reflecting discontinuities in subsurface.

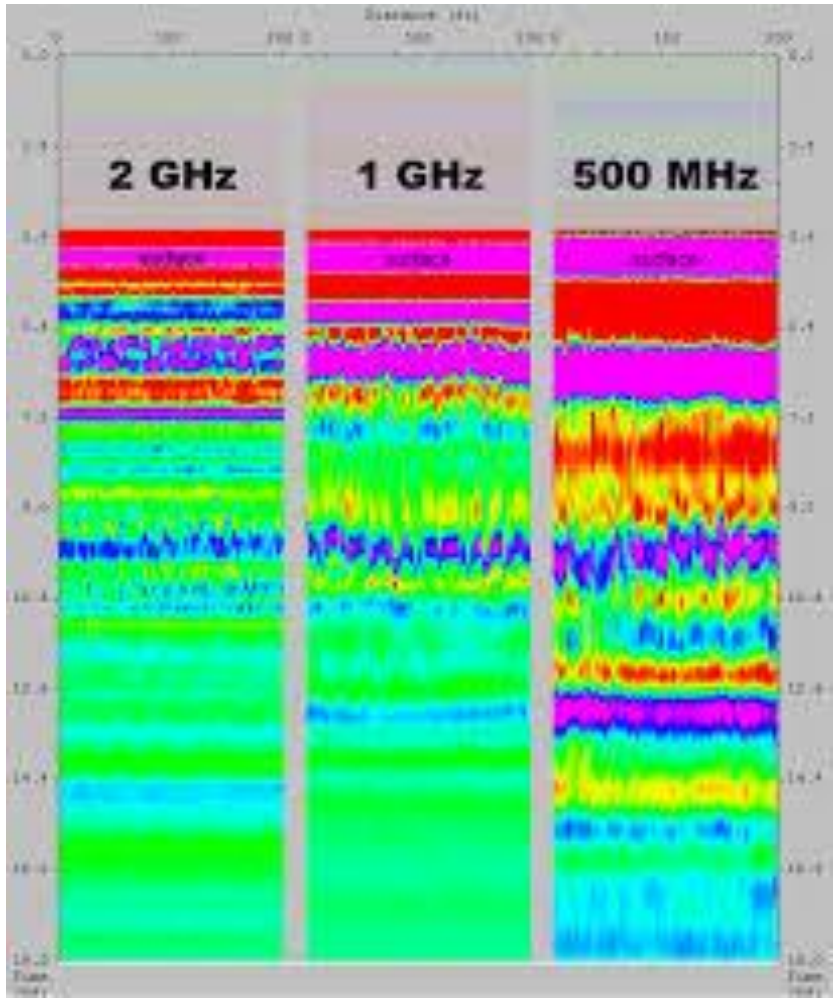


Operating Frequency

- There is optimum choice of freq. of operation to achieve best performance in terms of depth and ability.
- The choice is between 1 and 5000 MHZ.
- Generally Low freq. are used for deep probing (>50 m) and high freq. are used for shallow probing (<50 m).
- The Initial freq. estimation formula:

$$f = \frac{150}{X\sqrt{K}}(MHz)$$

- X- specify a desire spatial resolution
- K-relative permittivity (dielectric constant) of most material



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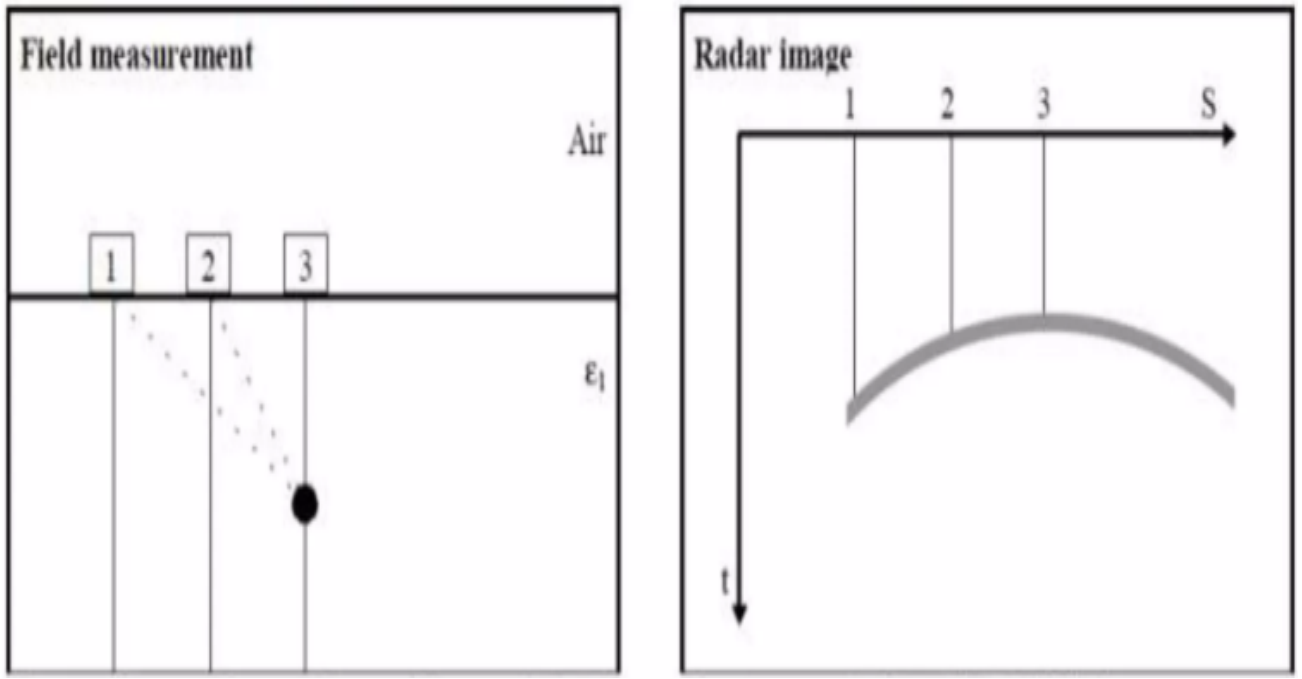
Resolution (Depends on frequency)

- Low resolution (a few MHZ) give good depth penetration, but low resolution (more than 50m).
- High frequencies (about a GHZ) can resolve cm-sized objects, but penetrate only a meter or less (less than 50 m).
- In archaeology, resolution is generally more important that depth, so high frequencies are commonly used.
- In geologic survey, depth is generally more important than resolution, so low freq. are used to survey.

Generation of Hyperbola in radar images

- GPR image shows buried objects in hyperbolic shape
- Top of hyperbola represents the exact location of buried object.
- GPR images are obtained by using a single radio-wave frequency.
- Regular radar image interpreters decide the exact location and depths of targets depending on a direct measurement from the top of the hyperbola.



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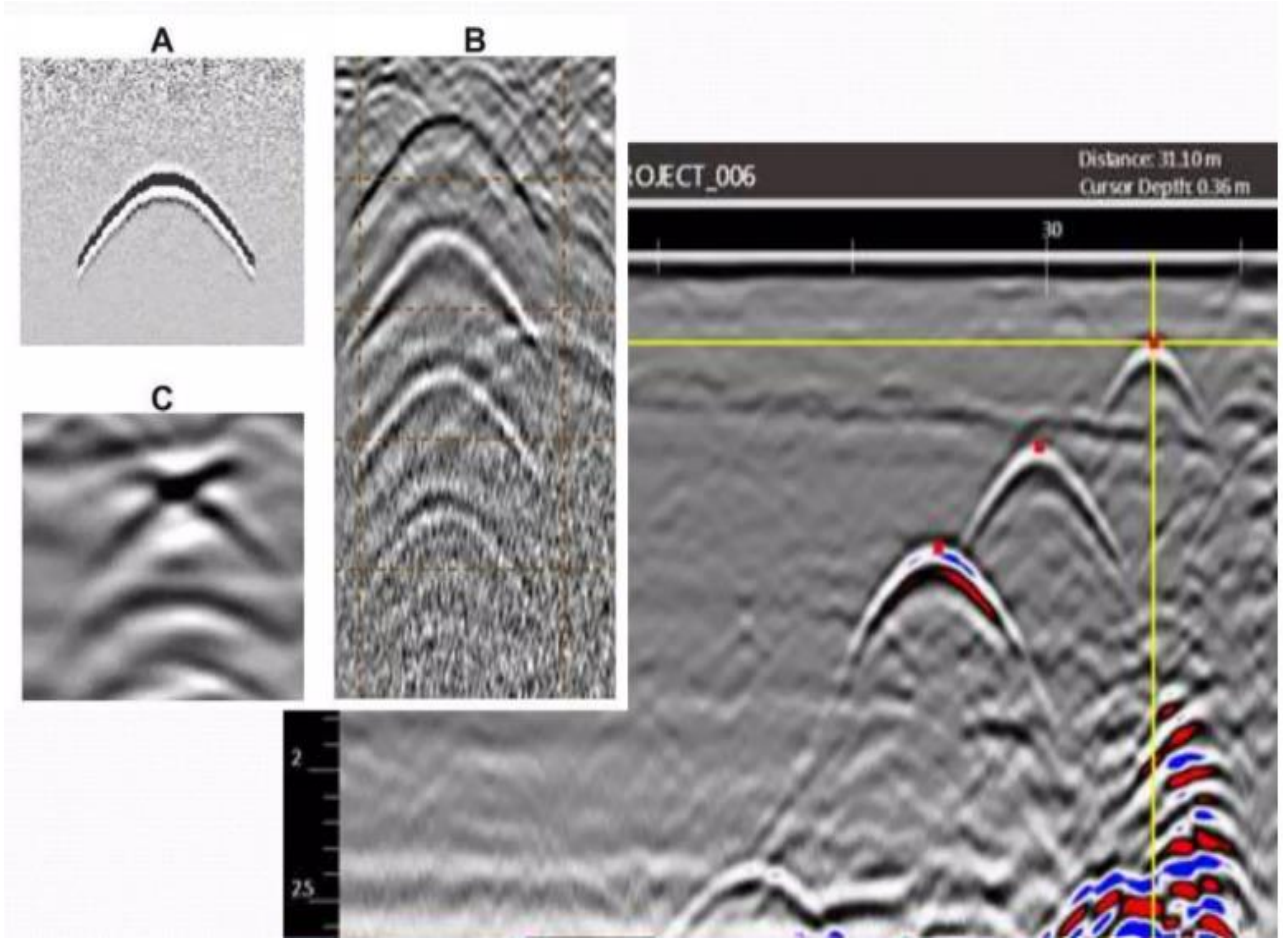

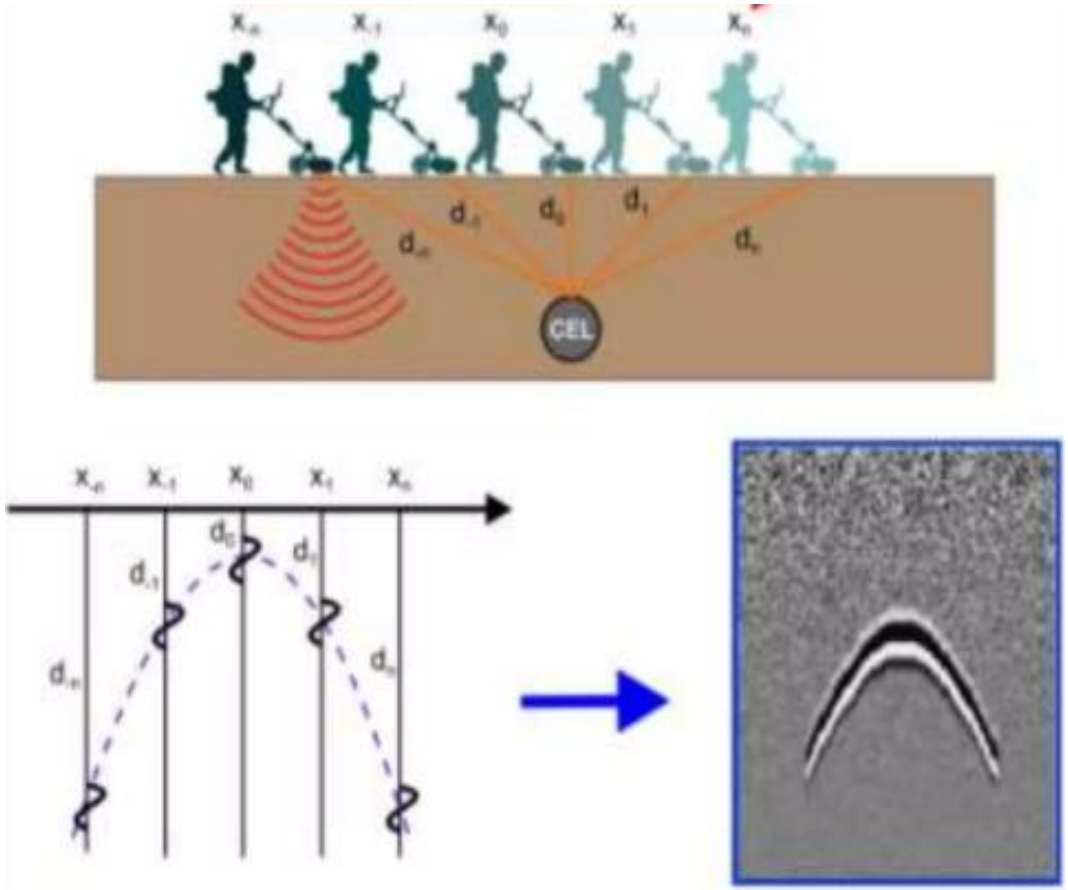

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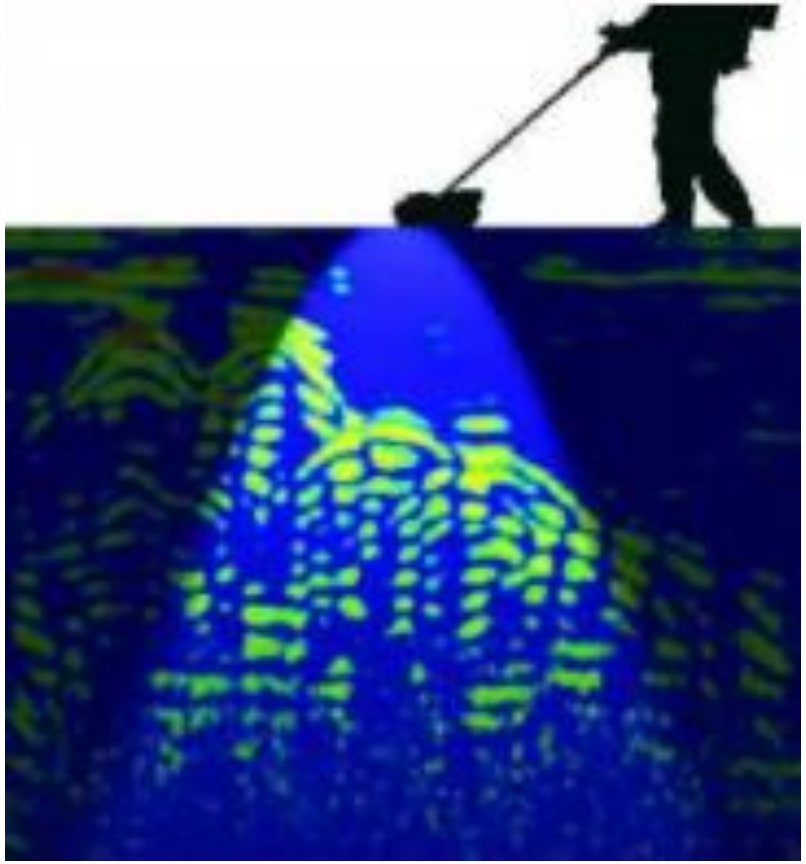
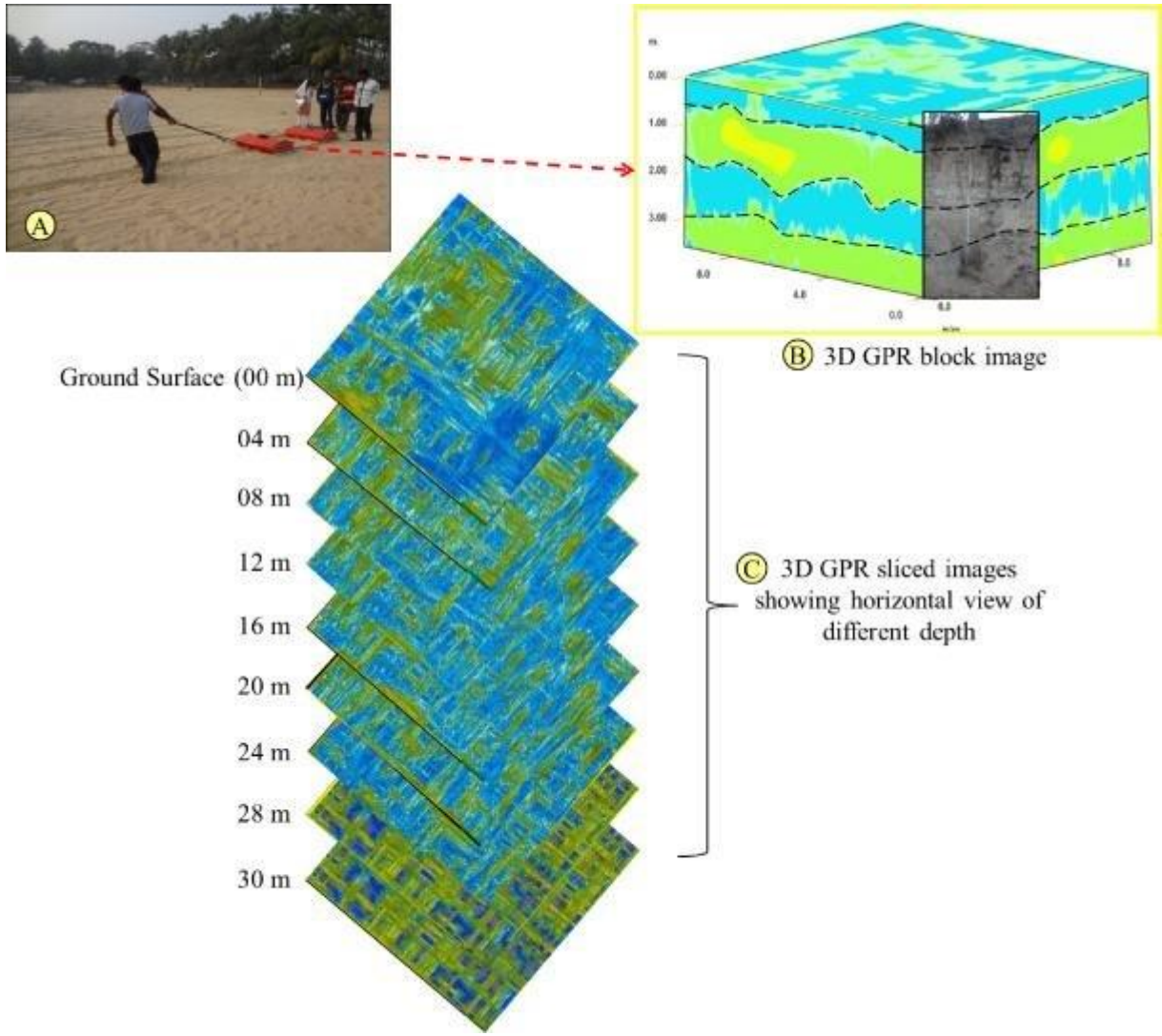
- Creation of hyperbola depends on:
  - Intensity of frequency
  - Object distance from transmitter
  - Angle/cone



3D GPR Image

- Multiple lines of data systematically collected over an area may be used to construct three-dimensional or tomographic images.
- Data may be presented as 3-D blocks or horizontal or vertical slices.



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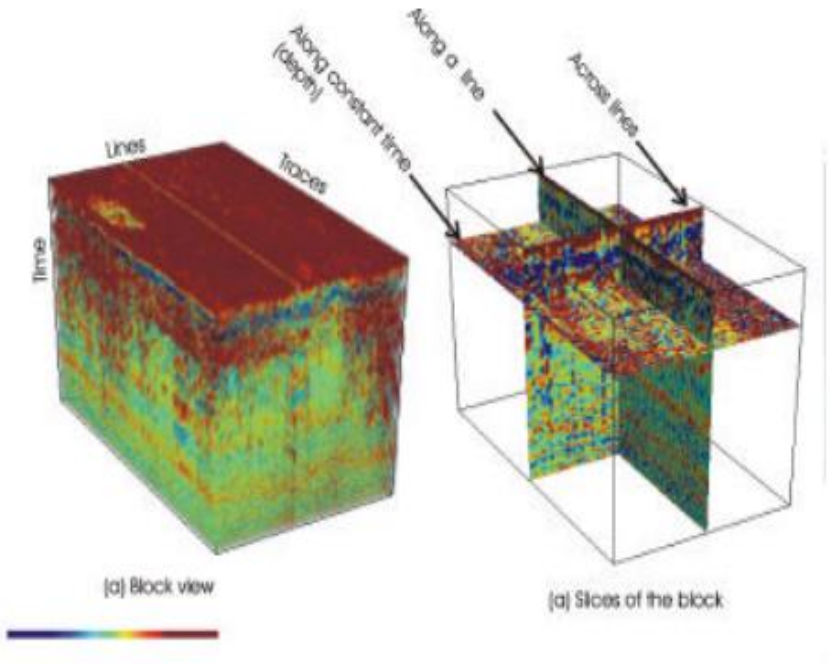
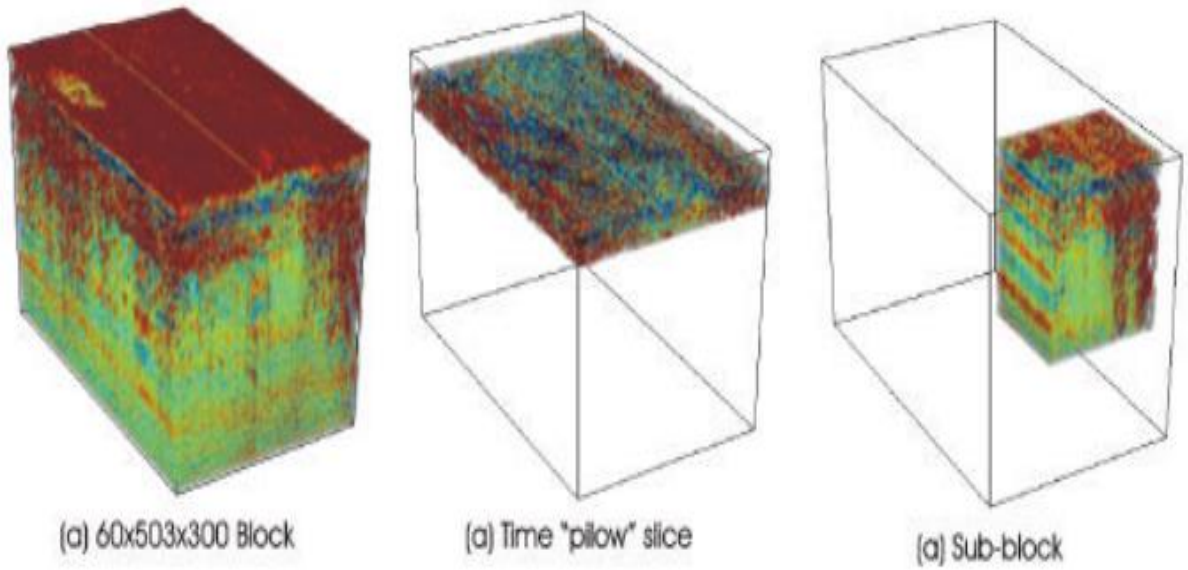


Dissecting a three-dimensional block into slices



Block and sub-block views to focus on a particular region inside of a block

Components of GPR

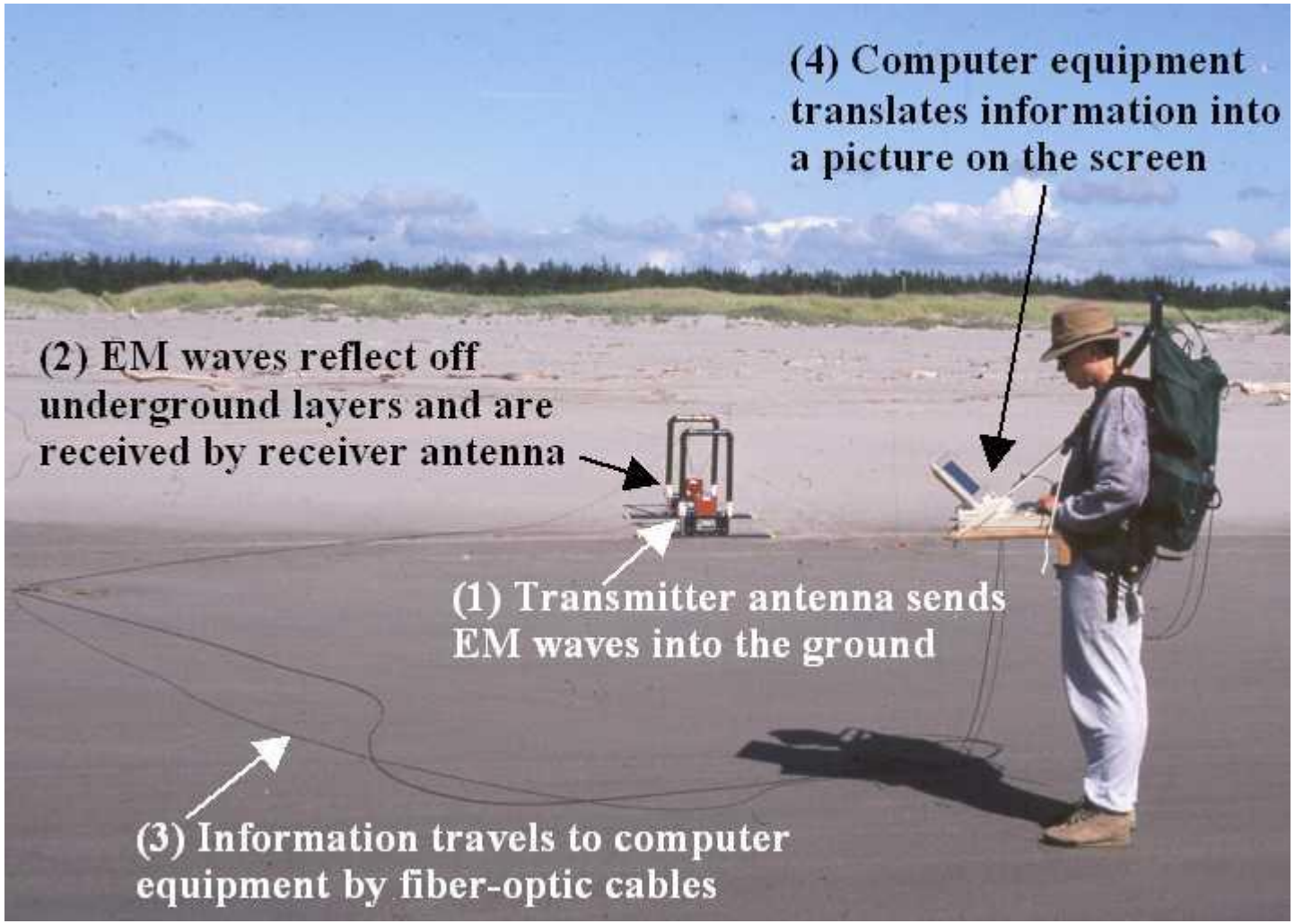
- Transmitter antenna:
  - The GPR transmitter produces the short duration high power RF pulses of energy that are radiated into ground by the antenna.

- Receiver Antenna:
  - GPR receiver receive reflected/backscatters RF pulses of energy from the object which are located in beneath the ground.
  - The freq. of antenna determines the depth of penetration and the resolution.
  - Higher the freq. better the resolution but at the expense of depth of penetration.

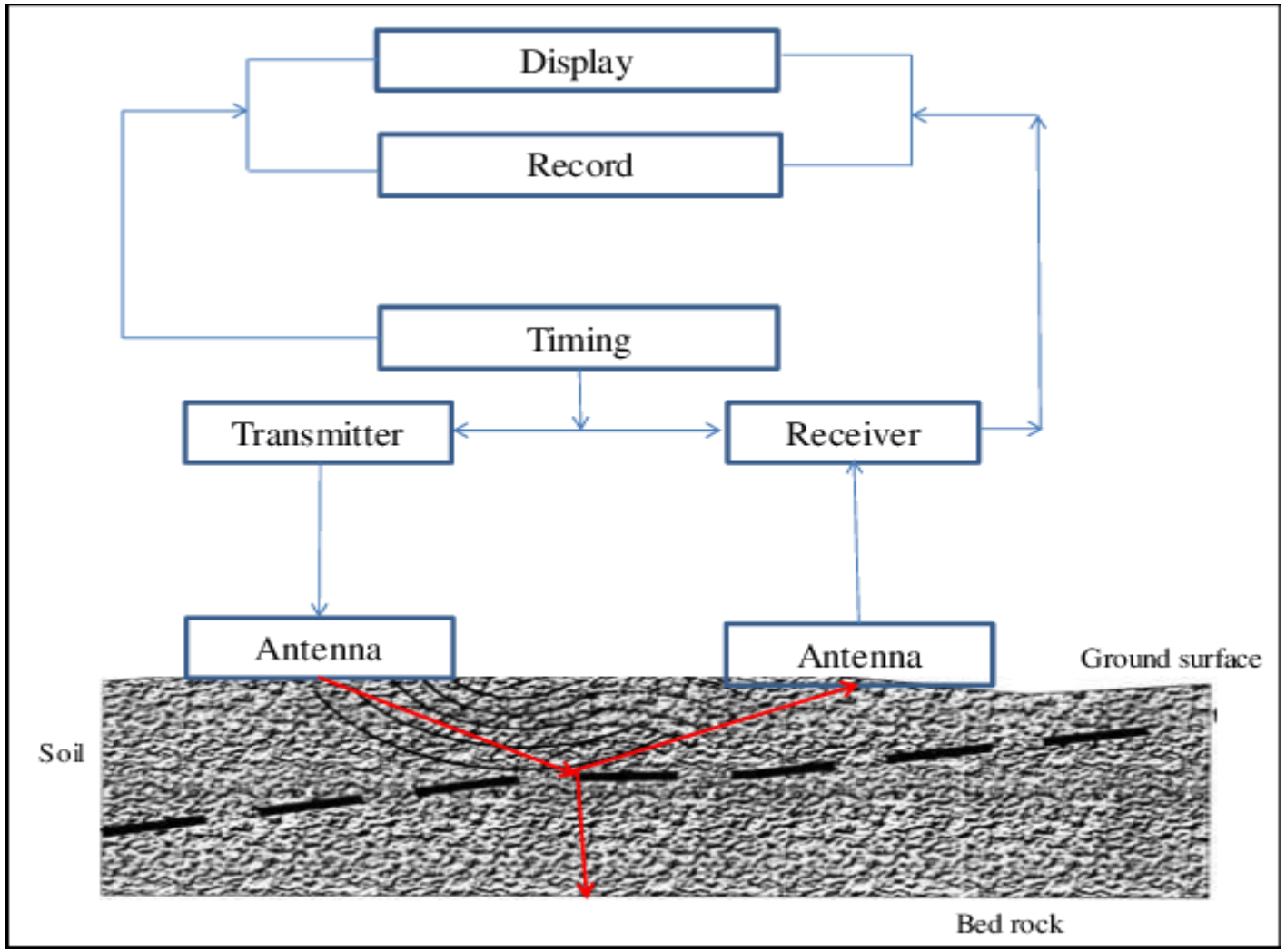
- Control Unit:
  - Control unit is the brain center for the GPR system
  - It is responsible for coordinating the operation of the subordinate components.
  - It has the ability to control all functions of GPR and it is one of the main junction of data flow.

Contd…

- Display unit:
  - Display continues cross sectional profile or record of subsurface features to operator.
- Power unit:
  - Provide power to all GPR system to activate work.
- Softwares:
  - RADAN
  - GPRmax
  - GPRslice



Components of GPR



Advantages of GPR

- High speed recording (8km/hr)
- Able to detect voids and trenches
- Able to determine depths and lengths of targets
- Colors also improve data quality
- Easy to handle
- Changeable frequency(1Mhz - 5 Ghz)
- Real time display unit represent cross sectional profile
- Used a lot in applications

Disadvantages of GPR

- Region irradiated by the antenna is limited to cone-shaped volume directly below antenna
- Cracks and delamination's are not easy to detect unless moisture is also present in the cracks or regions of the delamination.
- Pulses from high resolution antenna have limited depth of penetration (400 to 750 mm).
- The behaviour of electromagnetic pulses propagating through reinforced concrete structures is not completely known.
- Experienced operator required to operate equipment and interpret results.
- Large amount of data obtained during scans.

Conclusion

- GPR has been developed into a sophisticated technique that can provide detailed images of the near surface.
- GPR is a time-dependent geophysical technique that can provide a 3-D pseudo image of the subsurface, including the forth dimension of colour.
- It can also provide accurate information of depth estimation for many common subsurface objects.
- GPR responds to both metallic and non-metallic objects
- In the field of earth science, it used to study bedrock, soils, groundwater, and ice depth estimation.
- GPR is an excellent tool for mapping nearly any inhomogeneity in the subsurface that is characterized by a small difference in density, or porosity.

Thank you

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