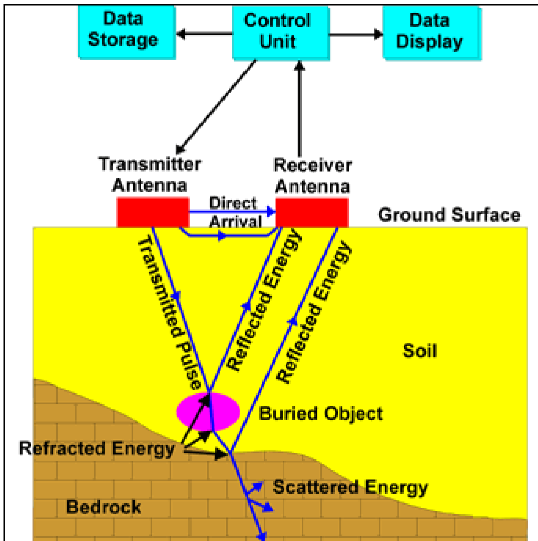
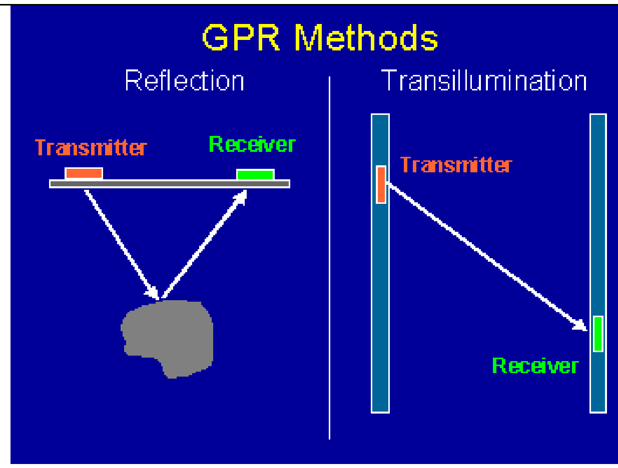
Ground Penetrating Radar (GPR)





Frequency range: 10–1000 MHz. Depths: 4–50 m Cost: $50K and more

Applications

GPR is used to map geologic conditions that include depth to bedrock, depth to the water table, depth and thickness of soil and sediment strata on land and under fresh water bodies, and the location of subsurface cavities and fractures in bedrock. Other applications include the location of objects such as pipes, drums, tanks, cables, and boulders, mapping landfill and trench boundaries mapping contaminants, and conducting archeological investigations.

Speed of EM Wave

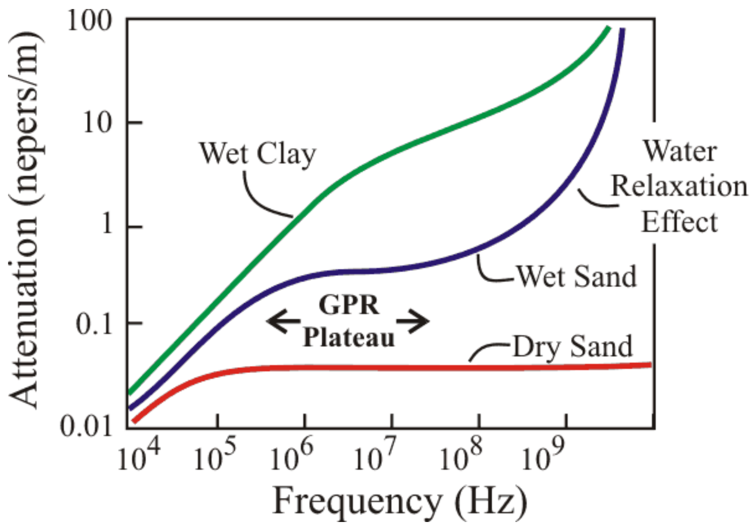
$$c = \sqrt{\frac{\mu}{\varepsilon}} = \sqrt{\frac{\mu_0}{\varepsilon_0}}\sqrt{\frac{\mu_r}{\varepsilon_r}} = c\sqrt{\frac{u_r}{\varepsilon_r}} \propto c\sqrt{\frac{1}{\varepsilon_r}}$$

Material	Relative Permittivity, ε_r	Pulse Velocities, m/ns	Conductivity, mS/m
Air	1	0.3	0
Fresh water	81	0.033	0.10-30
Sand (dry)	4-6	0.15-0.12	0.0001-1
Sand (saturated)	25	0.0055	0.1-1
Silt (saturated)	10	0.095	1-10
Clay (saturated)	8-12	0.106-0.087	100-1000
Granite (dry)	5	0 .134	0.00001
Concrete	5-10	0.134-0.095	
Asphalt	3-5	0.173-0.134	

Attenuation and Penetration

$$|E_r| = |E_0 e^{-\alpha x}|$$

E_r and E_0 are the received and transmitted magnitude of the Electric field of the EM pulse, x is the propagation distance, and α is the attenuation in nepers/m.

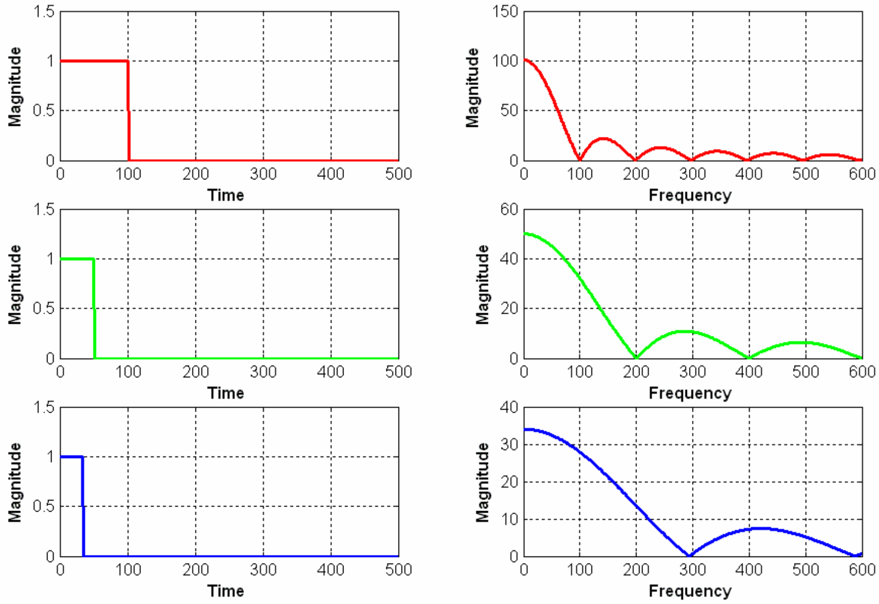


Attenuation in nepers/m of some materials

Example. For dry sand the attenuation is about 0.5 nepers/m. Thus, after one meter the magnitude of the EM field has fallen to $e^{-0.5\times1} = 0.61$. In other words, after one meter the amplitude is 20log(0.6) = 4.34 dB.

Lowering frequency improves depth of exploration because attenuation primarily increases with frequency. As frequency decreases, however, two other fundamental aspects of the GPR measurement come into play. First, reducing frequency results in a loss of resolution. Second, if frequency is too low, electromagnetic fields no longer travel as waves but diffuse which is the realm of inductive EM or eddy current measurements.

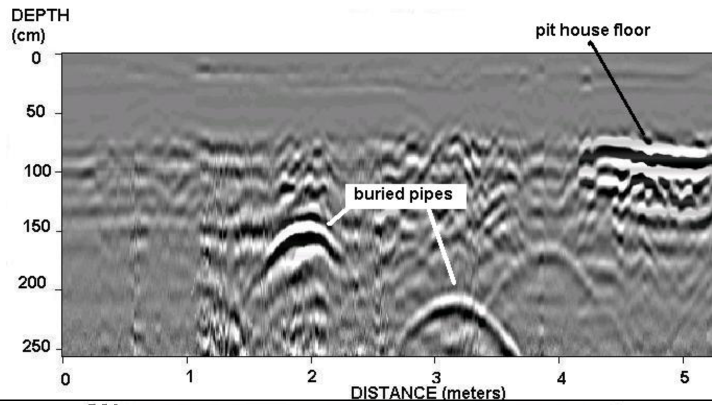
Time-Bandwidth., Spatial Resolution

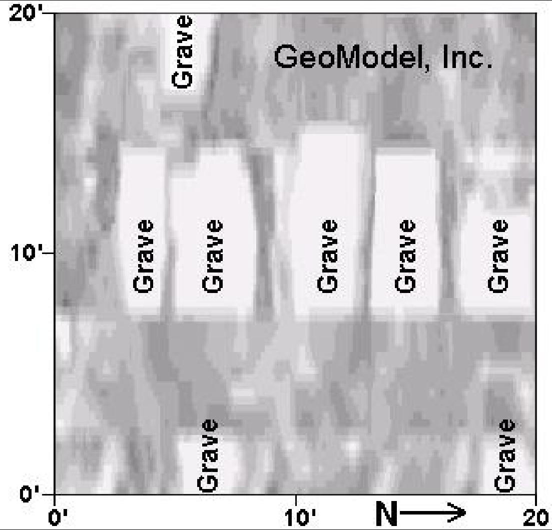


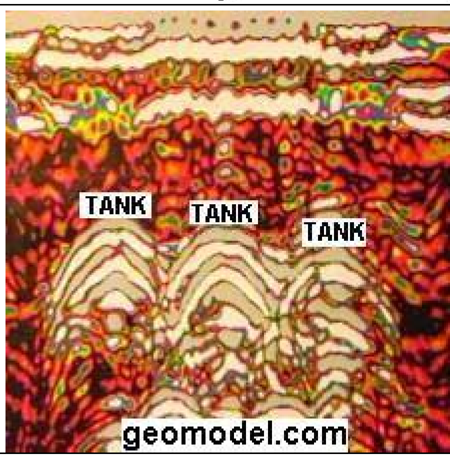
$$|X(f)| = \tau |\text{sinc}(f\tau)|$$

Bandwidth ~ $1/\tau$

Sample Measurements







Sample GPR Systems

	
400 MHz	40 MHz
	
500 MHz	

SPECIFICATIONS:

Transmit center frequency..............500MHz
Average radiated power 16mW
Receiver type................Equivalent time sampling
Input noise..........................<10uV RMS
Dynamic Range input...................120db
Dynamic Range digitized 96db
Digital resolution.................... 16 bits
Antenna type.................Proprietary tapered
.... impedance travelling wave
Antenna impedance..................... 50 ohms
Antenna VSWR.........................<1.6:1
System weight........................ 12.5kg

Websites

http://fate.clu-in.org/GPR_main.html
http://www.du.edu/~lconyer/what_is_gpr.htm
Ground Penetrating Radar Fundamentals. http://www.geology.ohio-state.edu/~jeff/Library/basics.pdf, and http://diwww.epfl.ch/lami/detec/gprhard.html