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# Standard Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation[1]

This standard is issued under the fixed designation D6432; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 *Purpose and Application*:

1.1.1 This guide covers the equipment, field procedures, and interpretation methods for the assessment of subsurface materials using the impulse Ground Penetrating Radar (GPR) Method. GPR is most often employed as a technique that uses high-frequency electromagnetic (EM) waves (from 10 to 3000 MHz) to acquire subsurface information. GPR detects changes in EM properties (dielectric permittivity, conductivity, and magnetic permeability), that in a geologic setting, are a function of soil and rock material, water content, and bulk density. Data are normally acquired using antennas placed on the ground surface or in boreholes. The transmitting antenna radiates EM waves that propagate in the subsurface and reflect from boundaries at which there are EM property contrasts. The receiving GPR antenna records the reflected waves over a selectable time range. The depths to the reflecting interfaces are calculated from the arrival times in the GPR data if the EM propagation velocity in the subsurface can be estimated or measured.

1.1.2 GPR measurements as described in this guide are used in geologic, engineering, hydrologic, and environmental applications. The GPR method is used to map geologic conditions that include depth to bedrock, depth to the water table (Wright et al (**1**)[2]), depth and thickness of soil strata on land and under fresh water bodies (Beres and Haeni (**2**)), and the location of subsurface cavities and fractures in bedrock (Ulriksen (**3**) and Imse and Levine (**4**)). Other applications include the location of objects such as pipes, drums, tanks, cables, and boulders , mapping landfill and trench boundaries (Benson et al (**6**)), mapping contaminants (Cosgrave et al (**7**); Brewster and Annan (**8**); Daniels et al (**9**)), conducting archaeological (Vaughan (**10**)) and forensic investigations (Davenport et al (**11**)), inspection of brick, masonry, and concrete structures, roads and railroad trackbed studies (Ulriksen (**3**)), and highway bridge scour studies (Placzek and Haeni (**12**)). Additional applications and case studies can be found in the various *Proceedings of the International Conferences on Ground Penetrating Radar* (Lucius et al (**13**); Hannien and Autio, (**14**), Redman, (**15**); Sato, (**16**); Plumb (**17**)), various *Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems* (Environmental and Engineering Geophysical Society, 1988–1998), and The Ground Penetrating Radar Workshop (Pilon (**18**) ), EPA (**19**~~), and Daniels~~ **), Daniels (20), and Jol (21) provide overviews of the GPR method.**

1.1.3 The geotechnical industry uses English or SI units.

1.2 *Limitations*:

1.2.1 This guide provides an overview of the impulse GPR method. It does not address details of the theory, field procedures, or interpretation of the data. References are included for that purpose and are considered an essential part of this guide. It is recommended that the user of the GPR method be familiar with the relevant material within this guide and the references cited in the text and with Guides D420, D5730, D5753, D6429, and D6235.

1.2.2 This guide is limited to the commonly used approach to GPR measurements from the ground surface. The method can be adapted for a number of special uses on ice (Haeni et al (**~~21~~22**); Wright et al (**~~22~~23**)), within or between boreholes (Lane et al (**~~23~~24**); Lane et al (**~~24~~25**)), on water (Haeni (**~~25~~26**)), and airborne (Arcone et al (**~~25~~26**)) applications. A discussion of these other adaptations of GPR measurements is not included in this guide.

1.2.3 The approaches suggested in this guide for using GPR are the most commonly used, widely accepted, and proven; however, other approaches or modifications to using GPR that are technically sound may be substituted if technically justified and documented.

1.2.4 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional*

[1] This guide is under the jurisdiction of ASTM CommitteeD18 on Soil and Rock and is the direct responsibility of Subcommittee D18.01 on Surface and Subsurface Characterization.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

***A Summary of Changes section appears at the end of this standard.**

*~~judgements.~~judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a ~~project's~~project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

1.3 *Precautions*:

1.3.1 *It is the responsibility of the user of this guide to follow any precautions in the equipment manufacturer's recommendations and to establish appropriate health and safety practices.*

1.3.2 *If this guide method is used at sites with hazardous materials, operations, or equipment, it is the responsibility of the user of this guide to establish appropriate safety and health practices and to determine the applicability of any regulations prior to use.*

1.3.3 *This guide does not purport to address all of the safety concerns that may be associated with the use of the GPR method. It is the responsibility of the user of this guide to establish appropriate safety and health practices and to determine the applicability of regulations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[3]

D420 Guide to Site Characterization for Engineering Design and Construction Purposes

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D5730 Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Ground Water

D5753 Guide for Planning and Conducting Borehole Geophysical Logging

D6235 Practice for Expedited Site Characterization of Vadose Zone and Ground Water Contamination at Hazardous Waste Contaminated Sites

D6429 Guide for Selecting Surface Geophysical Methods



## 3. Terminology

3.1 *Definitions*:

3.1.1 Definitions shall be in accordance with the terms and symbols given in Terminology D653.

3.1.2 The majority of the technical terms used in this guide are defined in Sheriff **(27)**.

~~3.1.3*Additional Definitions*:~~

~~3.1.3.1~~

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *antenna, n*— a transmitting GPR antenna converts an excitation in the form of a voltage pulse or wave train into EM waves. A receiving GPR antenna converts energy contained in EM waves into voltages, which are regarded as GPR data.



~~3.1.3.2~~

3.2.2 *attenuation*~~—(~~*, n— wave,* (*1*) the loss of EM wave energy due to conduction currents associated with finite conductivity (σ) and the dielectric relaxation (also referred to as polarization loss) associated with the imaginary component of the permittivity (ε″), and magnetic relaxation associated with the imaginary component of magnetic permeability.

(*2*) The term "attenuation" is also sometimes used to refer to the loss in EM wave energy from all possible sources, including conduction currents, dielectric relaxation, scattering, and geometrical spreading.

~~3.1.3.3~~

3.2.3 *bandwidth, n*—The operating frequency range of an antenna that conforms to a specified standard (Balanis **(28)**). For GPR antennas, typically the bandwidth is defined by the upper and lower frequencies radiated from a transmitting GPR antenna that possess power that is 3 dB below the peak power radiated from the antenna at its resonant frequency. Sometimes the ratio of the upper and lower 3-dB frequencies is used to describe an antenna's bandwidth. For example, if the upper and lower 3-dB frequencies of an antenna are 600 and 200 MHz, respectively, the bandwidth of the antenna is said to be 3:1. In GPR system design, the ratio of the difference between the upper frequency minus the lower frequency to the center frequency is commonly used. In the preceding case, one would have a ratio of 400:400 or 1:1.

~~3.1.3.4~~

3.2.4 *bistatic, adj*—the survey method that ~~utilizes~~ uses two antennas. One antenna radiates the EM waves and the other antenna receives the reflected waves.

~~3.1.3.5~~3.2.5 *conductivity, n— electrical,* the ability of a material to support an electrical current (material property that describes the movement of electrons or ions) due to an applied electrical field. The units of conductivity are Siemens/metre (S/m).

~~3.1.3.6~~3.2.6 *control unit* (C/U), *n*—An electronic instrument that controls GPR data collection. The control unit may also process, display, and store the GPR data.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.