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Lightning Conduction Ground Rods: Configurations & Testing For Tree Protection

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Grounding resistance can be reduced by increasing ground rod length. Grounding resistance can also be reduced by using different rod configurations and positions. Rod depth below the soil surface influences grounding resistance. Use of multiple rods, and horizontal or vertical configurations, also impact resistance. (Saraoja 1977) Horizontal grounding rods packed in trenches at some distance below the soil surface may be alternatives to vertically driven rods when addressing severe soil or site constraints, like rock near the surface.

Rod Depth

Figure 1 shows eight feet long, 0.5 inch diameter rods in various configurations at three soil depths. The four configurations include three horizontal grounding lay-outs (A , B, & C), and one traditional vertically driven rod (D). Grounds A and B use two connected rods and grounds C and D use a single grounding rod. Grounding resistance changes (under standard conditions) are shown as rod depth changes. This figure was designed to examine grounding rod depth only and should not be used for comparing configurations. Ground B is best at lowering resistance with increasing depth.

Ground A is a horizontally buried, V-shaped rod fork. Ground B is a horizontally buried, parallel rod system separated by one rod length. Ground C is a horizontally buried, single rod. Ground D is a vertically driven single rod whose depth value is determined from where the top of the rod is below the soil surface. For example, for each of the four rod configuration shown, increasing rod depth below one foot reduces resistance by as much as 25%. Deeper placement maximizes the grounding volume impacted.

Figure 2 demonstrates how soil depth changes grounding resistance for a single, traditional, vertically driven rod (eight feet long, 0.5 inch diameter). This figure demonstrates reduction of grounding resistance as rod depth increases from the soil surface. For example, if the rod is driven three feet into soil, grounding resistance would be reduced by as much as 31%, compared to a rod with its top end at the soil surface. Remember effective grounding reduces electrical resistance.

Rod Arranging

Figure 3 uses three of the same configurations used earlier to show resistance changes due only to configuration of the ground rods. The comparisons in this figure demonstrate how changing horizontally placed grounding systems in various ways change electrical resistances. For example, selecting either configuration A, a double rod fork, or selecting configuration B, double parallel rods, provides different electrical resistances. Selecting configuration B would reduce electrical resistance by 29% from configuration A. Selecting configuration A would increase electrical resistance by 41% from configuration B. Note configuration B has the lowest electrical resistance of all the configurations considered.

Figure 4 compares electrical resistance differences between single rods (8 feet long, 0.5 inch diameter) either placed horizontally at a one foot depth in the soil or driven vertically until the top of the rod is at a one foot soil depth. The vertical rod (configuration D) reduces electrical resistance by 21% compared with the horizontal rod with all other things being equal. A greater grounding rod length, a greater depth of installation, and vertical orientation tends to maximize grounding rod effectiveness and lower electrical resistance in a lightning conduction system.

Multi-Rods

To reduce electrical resistance, multiple vertical rods in a single line away from a tree can be used. Figure 5 shows resistance reduction is achieved with 2, 3, or 4 vertical rods compared with a single vertical rod. For each multi-rod configuration, this figure demonstrates how the distance between rods impacts grounding effectiveness. The wider rod spacings in multi-rod configurations, the more effective each ground rod becomes. Multiple rods placed too close together are not as effective as more widely spaced rods because of overlapping grounding volumes.

A graphical definition of rod placement is provided in Figure 6. This figure represents a single vertical ground rod driven one foot below the soil surface, and its associated grounding volume. Figure 7 represents two vertical rods with a separation of 12.6 feet. At the 90% grounding effectiveness value, the two rods function as only 1.8 rods because of the overlap in their grounding volumes.

Figure 8 shows rods spaced 8 feet apart. With rods 8 feet apart, grounding effectiveness is reduced to 84% of two independent vertical ground rod configurations. The two rods in the figure separated by 8 feet function like 1.68 rods because of overlapping grounding volumes. Ground rods must be placed far enough apart so each is fully functional.

Assuring Grounding

A lightning conduction system must have a low resistance ground component to be effective. As such, it is critical to measure electrical ground resistance. For many tree protection systems, dependence is based upon the experience / opinion of an installer and material quality to assure adequate electrical ground resistance. Because of grounding system configuration, soil properties, and site history, electrical ground resistance can vary greatly. One of the easiest means for measuring ground resistance is using the "fall-of-potential" method. (derived from Saraoja, 1977; USDoD-Military Handbook, 1987).

The quality (i.e. resistance) of tree lightning conduction system grounding components is measured as shown in Figure 9. The system's ground resistance is measured in ohms and determined by:

Electrical Resistance of the Ground System in ohms =

volts / current in amps

This figure demonstrates the lay-out of the measuring system. Electrical wire attachments to the lightning conduction system should be made on the down-cable at the tree just before it enters the soil, or just above any protective conduit present. These electrical connections should be separated by 5 inches from each other on the down-cable.

The location of the system ground rod(s) should be identified. The distances and depth measures for testing are based upon vertical ground rod length (value X). For horizontal long rods, or vertical or horizontal multi-rod configurations, the center of the ground rod system should be determined and the radius to system edge should be used as the ground rod length (value X).

Two stakes or rods, made of the same material as the ground rod should be used as testing probes. The voltage probe should be driven firmly into the soil away from the ground rod at a distance 7.5 times the ground rod length. The current probe should be driven firmly into the soil away from the ground rod at a distance of 12 times ground rod length. These probes should be never less than 1.5 feet in length, and should ideally be at least 1/5 the length of the ground rod. Because of soil and soil/water interactions in the rooting area, AC current should be used, but is not required. The resistance values should be less than 25 ohms, and preferably less than 10 ohms.

Professional Grade

Professional installers use a specialized, high internal resistance, ground resistance meter which provides all the leads, power, and internal measures, directly yielding ground resistance value in ohms. Small electrical multi-meters for use with home electronics should not be used. Professional ground resistance meters and power sources can be purchased for between $1,000 and $4,000 (costs from internet search). Commercial clamp-on meters can also be used for system resistance estimates. Because of the expense and time involved in setting-up the test, few tree lightning conduction systems are properly tested for ground resistance, and so, may not be functioning properly.

Normal Procedures

Lightning conduction systems, when properly grounded, ensure a quick, low resistance pathway for current flow which minimizes damage to trees. Grounding is key to effective lightning protection. Standard grounding recommendations for tree lightning conduction systems usually involve only one vertical 8-10 feet long rod 0.5 inches in diameter. Under most soil and site conditions this single vertical rod is adequate, upon measurement.

If soil and site limitations exist which prevent a vertical single rod from attaining a low enough electrical resistance, then multiple ground rods or other alternative grounding means are required. Tree lightning conduction systems are incapable of preventing tree and site damage if improperly grounded. Because grounding hardware and configurations are below ground and out-of-sight, visual inspection is a difficult process and repairing damage is time consuming. Installation of other below ground land-scape utilities can damage or destroy tree protection systems. Site and system vigilance are required over the life of the tree.

Citation:

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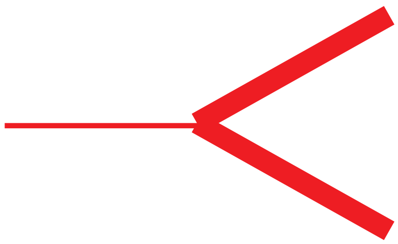
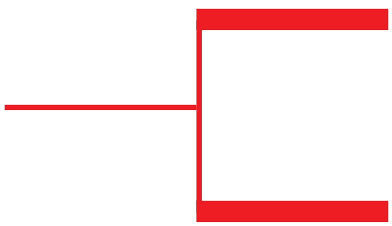
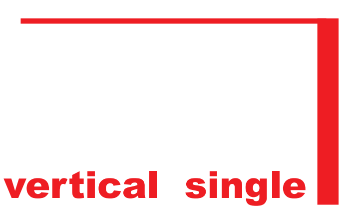
	depth in soil		
	1 ft.	2 ft.	3 ft.
A  double horizontal fork	X	0.91X	0.85X
B  double horizontal parallel	X	0.86X	0.75X
C  horizontal single	X	0.89X	0.81X
D  vertical single (depth is from rod top)	X	0.90X	0.83X

Figure 1: Change in electrical resistance with ground rods (8 feet long, 0.5 inch diameter) in various configurations as depth increases.

depth below soil surface	electrical resistance
0	X
1ft	0.83X
2ft	0.75X
3ft	0.69X

Figure 2: Change in electrical resistance for a single vertical rod (8 feet long, 0.5 inch diameter) as depth increases. Depth measured from rod top.

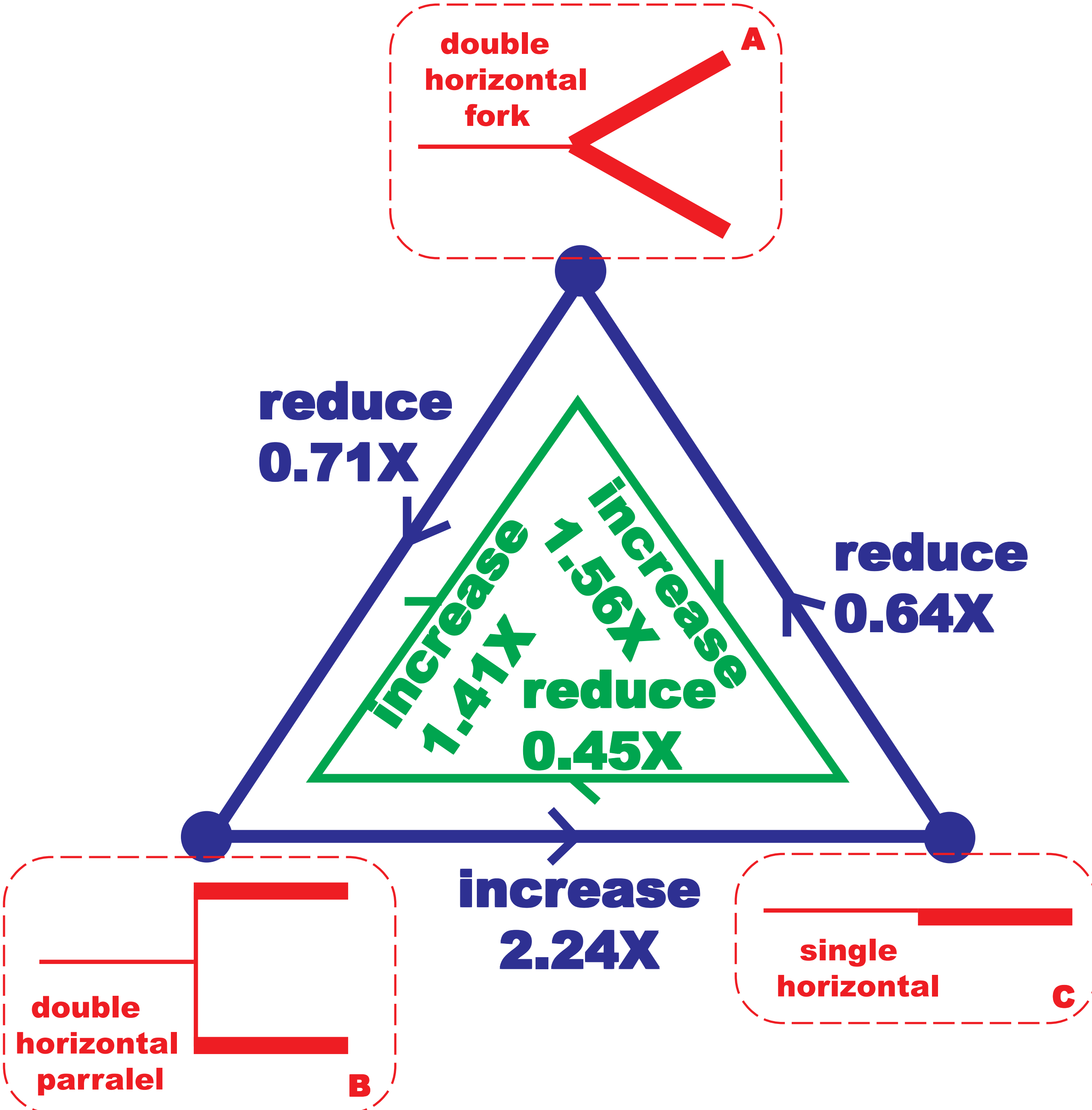


Figure 3: Change in electrical resistance betwen various grounding configurations of horizontally placed rods (8 feet long, 0.5 inch diameter). Here, configuration B has the lowest electrical resistance overall.

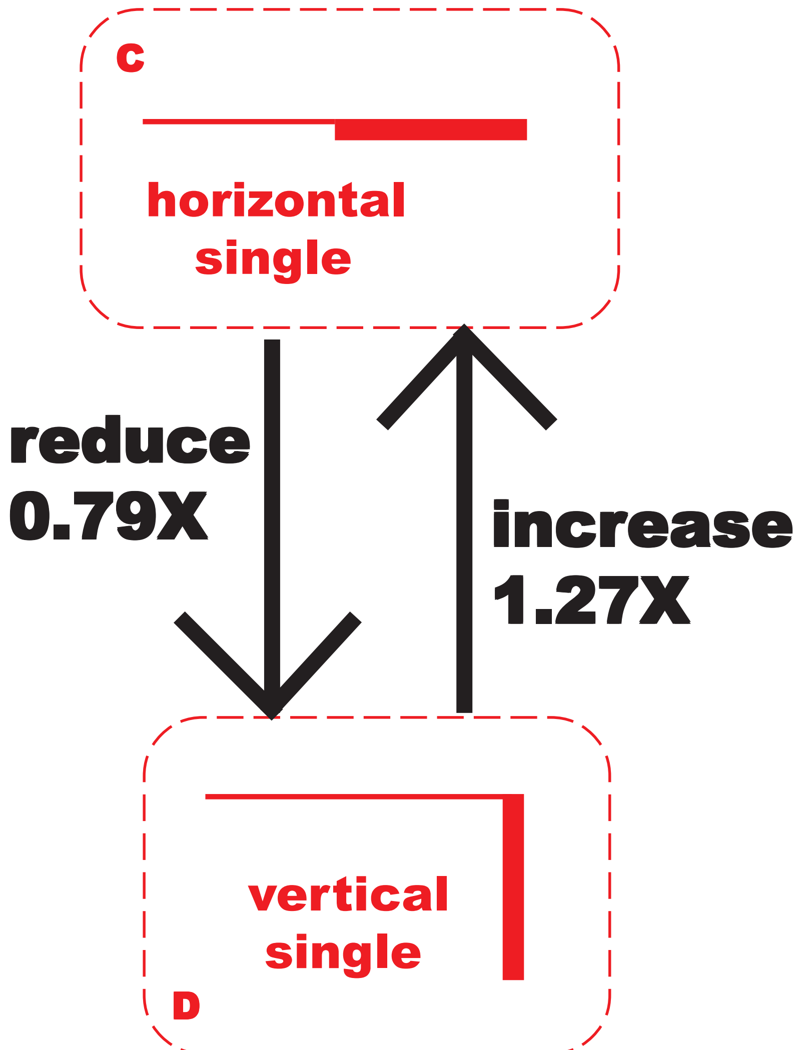


Figure 4: Change in electrical resistance around rods (8 feet long, 0.5 inch diameter) either placed horizontally at a one foot depth in soil or driven vertically until the top of the rod is at a one foot soil depth. Here, the vertically driven rod has the lowest electrical resistance of the two rod configurations.

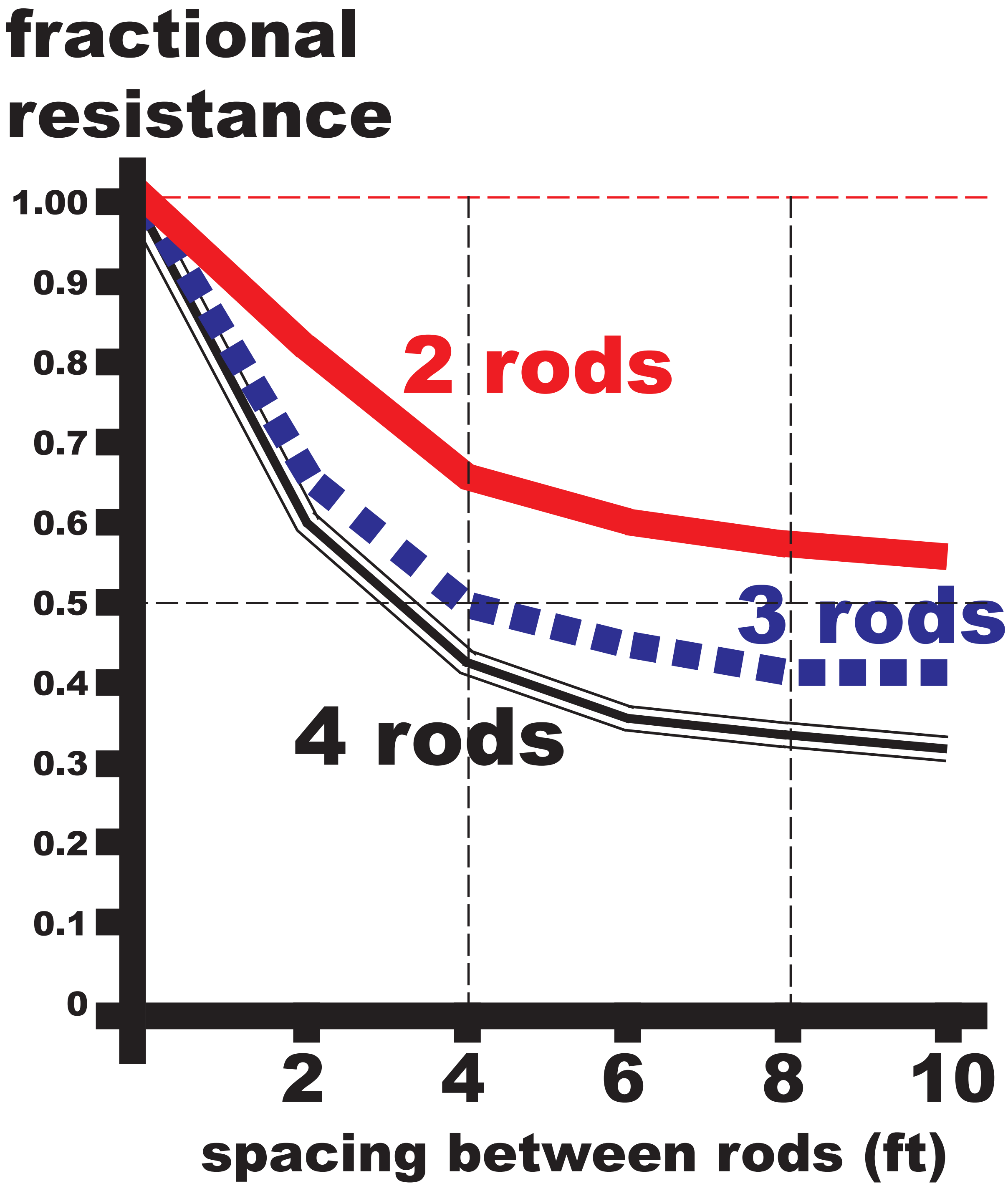


Figure 5: Spacing between rods in a multi-rod, parallel, straight-line system, compared with a single rod, and the associated fractional electrical resistance per rod. All rods are 8 feet long and 0.5 inches in diameter.

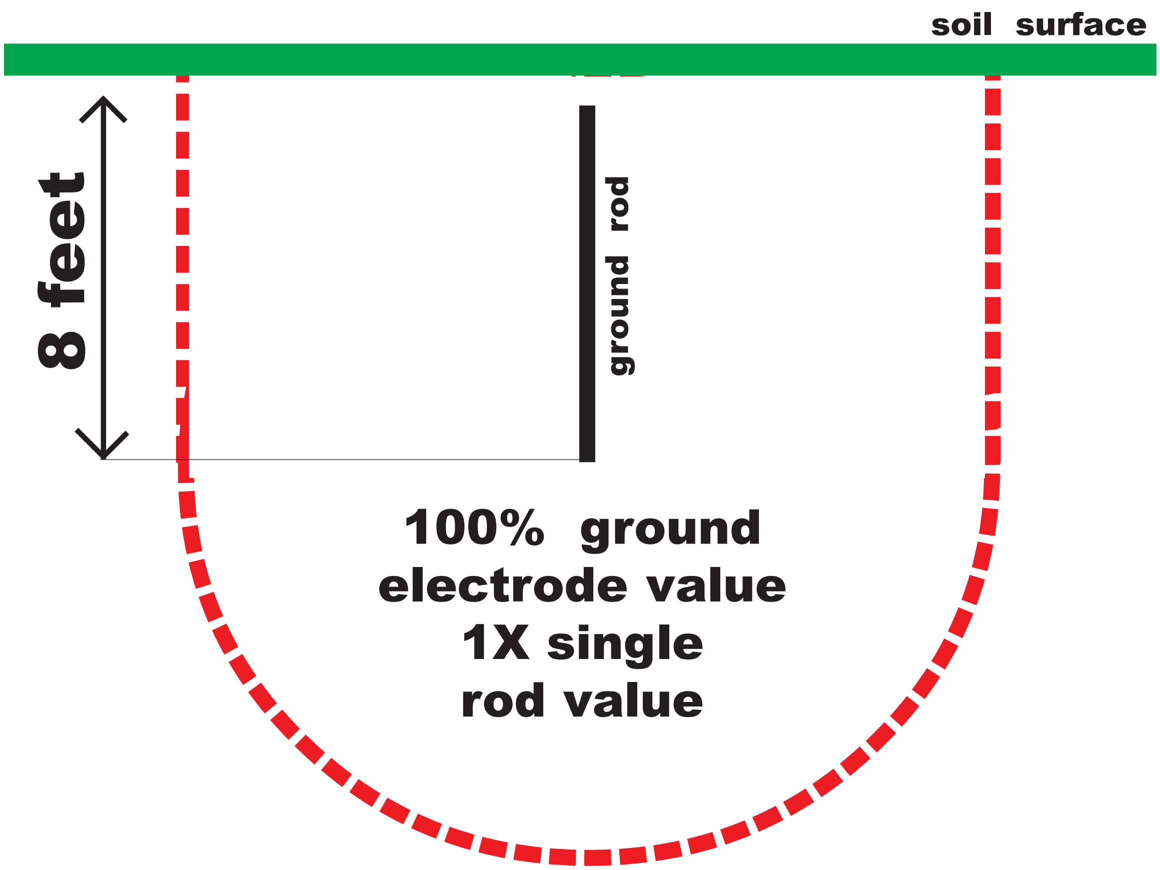


Figure 6: Side view of relative grounding areas for a single vertical rod 0.5 inches diameter & 8 feet long driven into soil.

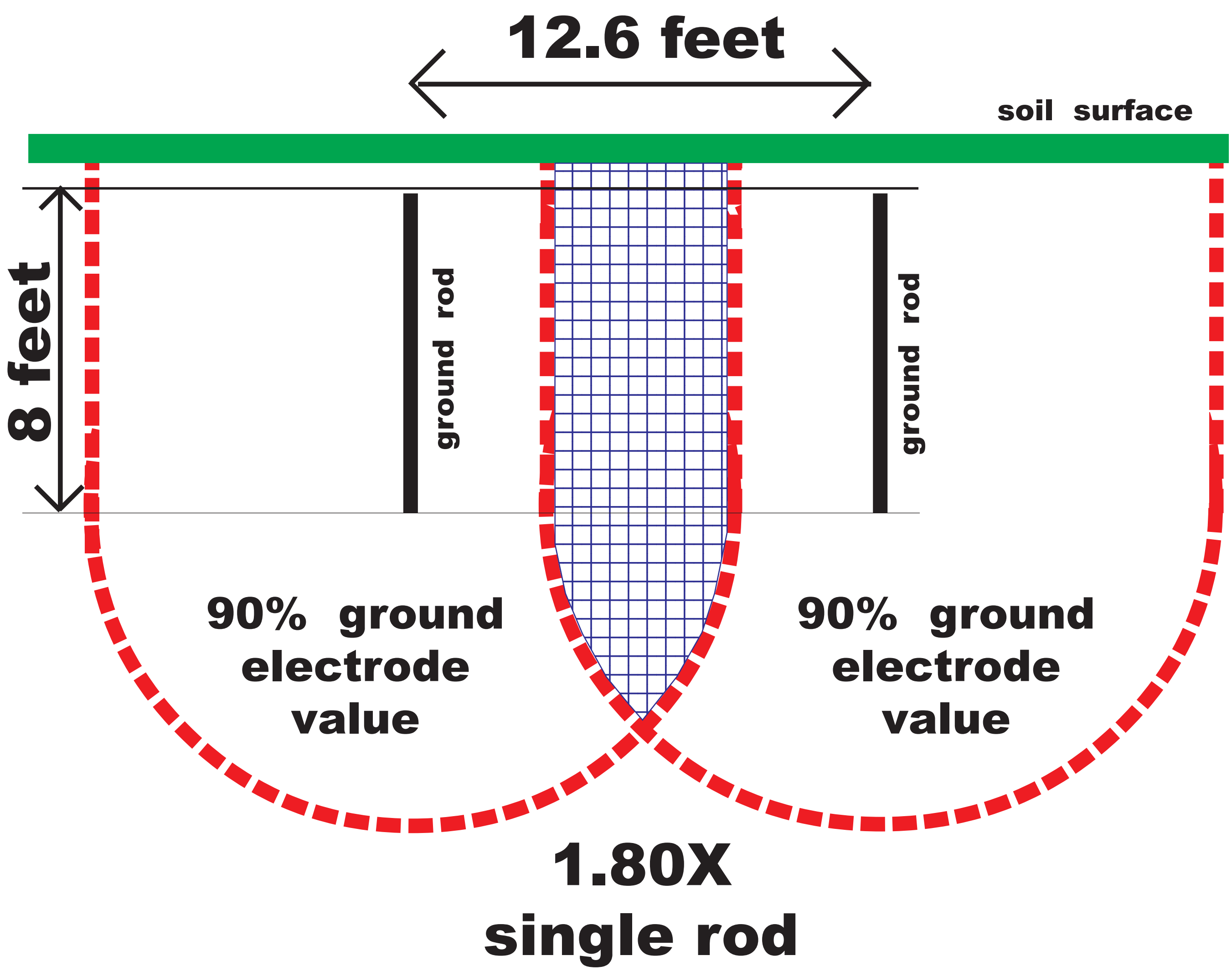


Figure 7: Side view of relative grounding areas for two vertical rods 0.5 inches diameter & 8 feet long driven into soil 12.6 feet apart.

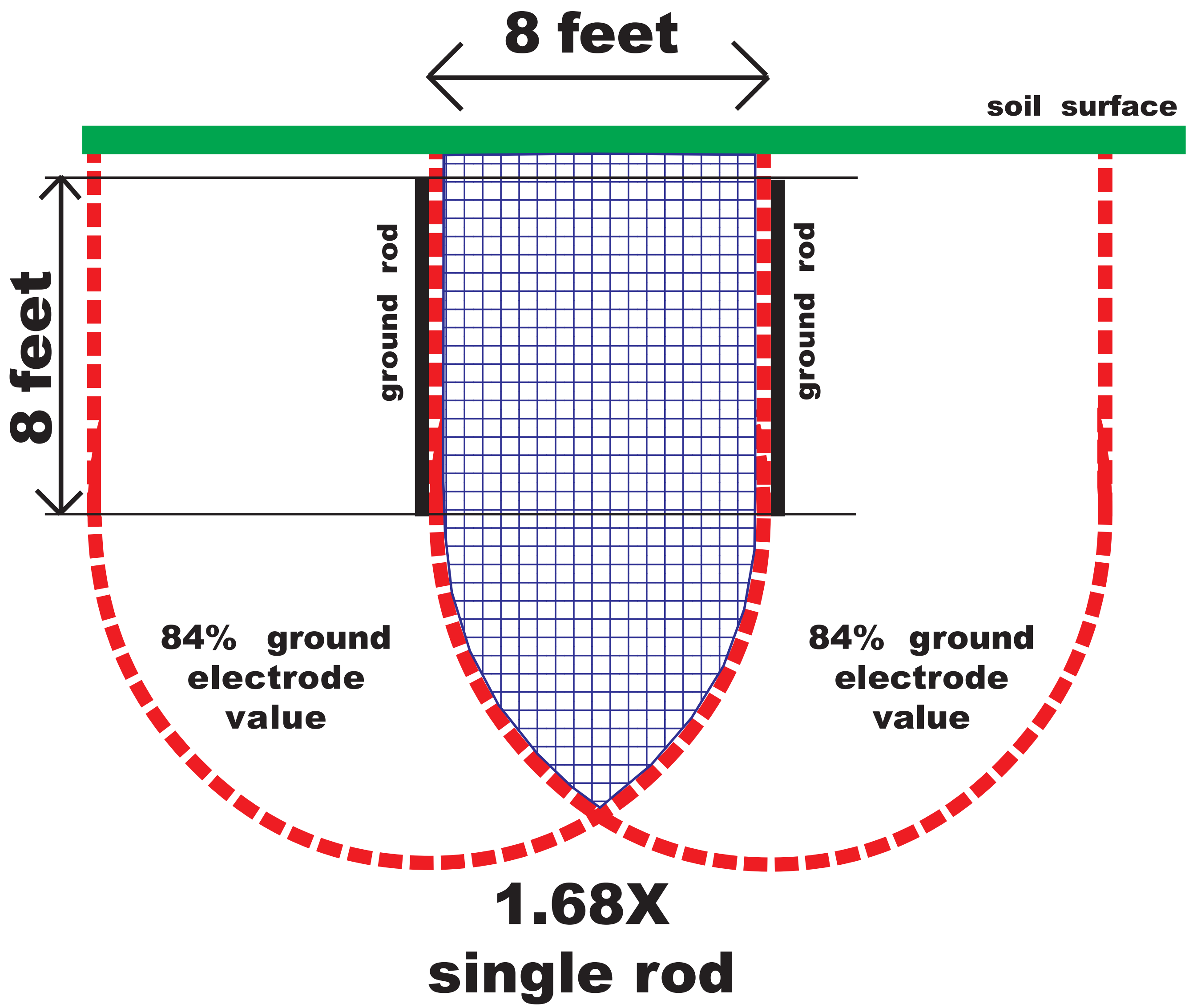


Figure 8: Grounding area & effectiveness for two vertical rods (0.5in diameter / 8ft long) driven into soil 8 feet apart.

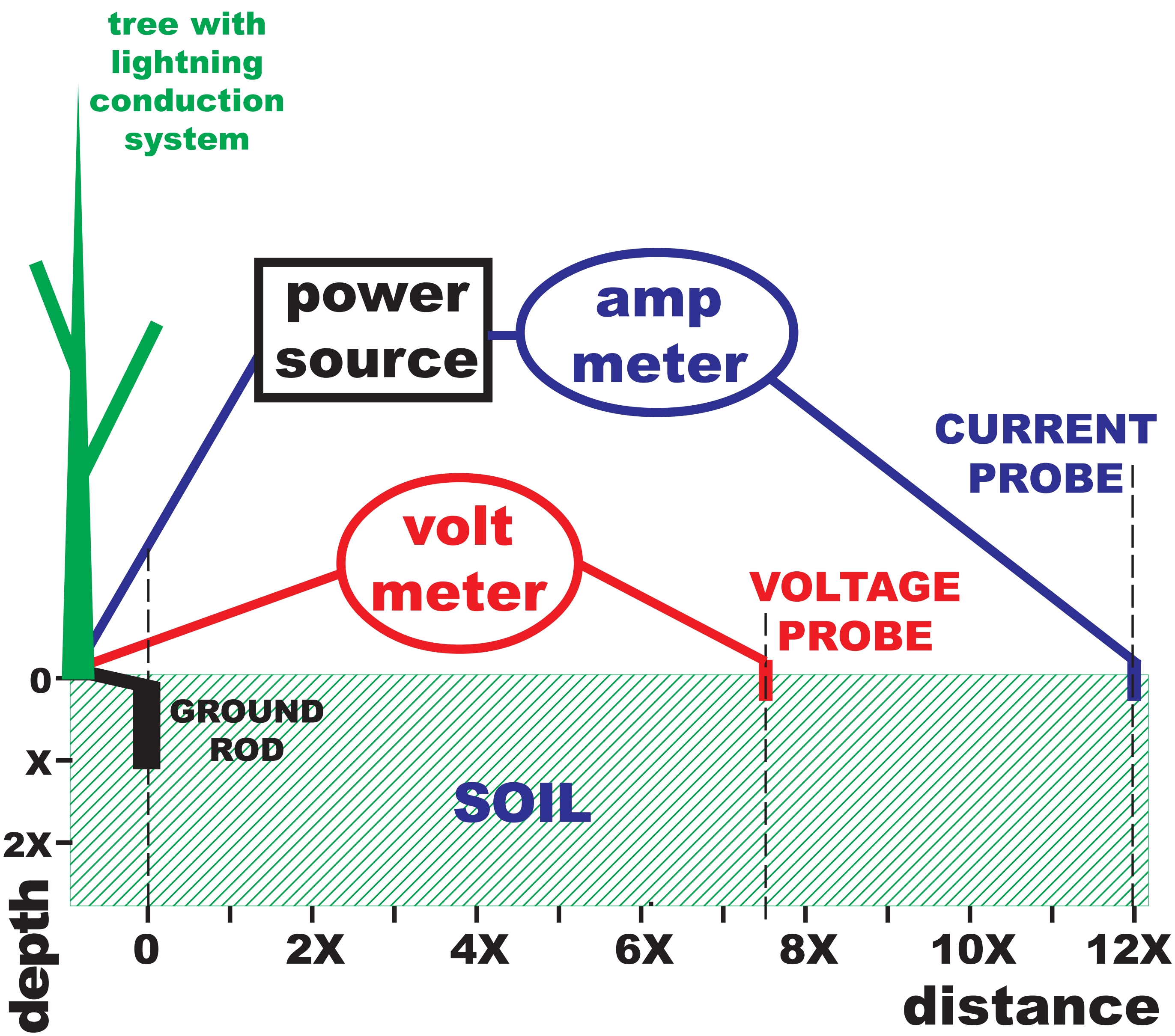


Figure 9: One method (fall-of-potential method) of measuring electrical resistance for the ground of a tree lightning conduction system which, in this figure, uses a single vertical ground rod.
(derived from Saraoja 1977; USDoD-Military Handbook, 1987).