Four Models used for Numerical Simulation of a Borehole Radar Antenna

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Open-File Report 2003-03-155

U.S. Department of the Interior
U.S. Geological Survey

ABSTRACT

In this report are four different models that represent an antenna used by personnel at the U.S. Geological Survey for crosswell investigations. The four models vary in complexity and concomitantly the accuracy with which they represent the actual antenna. These models are used in numerical simulations of the antenna to determine how it radiates radar waves.

INTRODUCTION

The transmitting antenna used at the U.S. Geological Survey was represented by four different models that were used in numerical simulations to calculate its radiation pattern. The complexity of the models and concomitantly the accuracy with which they represent the transmitting antenna varied.

These four models will be useful in future investigations, and so detailed descriptions of the models are in this report. Because the descriptions are straightforward, only a few remarks are necessary:

- The four models are labeled MODEL 1, MODEL 2, MODEL 3, and MODEL 4. The complexity of the models increases with model number. In other words, model 1 is the least complex, and model 4 is the most complex.
- Each model is described in a separate section of the report.
- The parts in the models are labeled with numbers. The same numbers are used for the same (or nearly the same) part in different models, to make their comparison somewhat easy. For example, the fiberglass cover in all models is labeled "3." Because of this method of numbering, the numbering for the parts in models 1, 2, and 3 is not consecutive. For example, model 1 has parts labeled "1" and "3," but not "2."
- The dimensions of the models are specified in the circular cylindrical coordinate system, and its origin is at the center of the driving point. The models have cylindrical symmetry, and so locations within the model are completely specified with just the radial and the axial distances (ρ and z, respectively). All dimensions use five digits to the right of the decimal place (for example, 0.00520).
- The electromagnetic properties are specified using three significant digits.
- In all four models, the space occupied by the coaxial cable (regions 27, 28, and 29) overlaps the space occupied by the driving point and the cylindrical conductors (region 10). While this appears to be an error, it is not. One finite difference grid is used for the coaxial cable, and another, larger grid is used for the rest of the antenna. The two grids are joined at the driving point.

MODEL 1

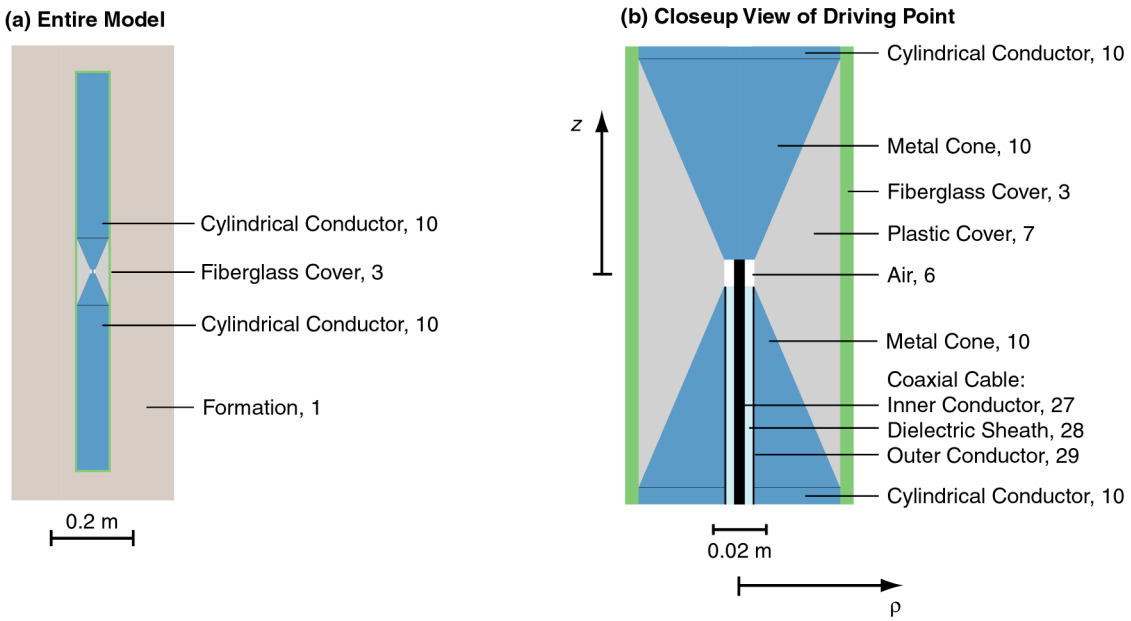

Figure 1. Model 1. Both diagrams are to scale and may be compared to the diagrams in Figures 2, 3, and 4. Each region of the model is referenced by a number. The electromagnetic properties and the dimensions of each region are listed in Tables 1 through 4.

Table 1. Regions of model 1, except for the coaxial cable (Figure 1). Type "s" refers to a region with standard or typical electromagnetic properties. Type "pc" refers to a region that is a perfect conductor. For such a region, both the relative dielectric permittivity and the relative magnetic permeability have no significance; consequently, the associated table entries are leaders (---). The dimensions of the regions are listed in Table 2.

Region Number	Description	Type	Electrical Conductivity (S/m)	Relative Dielectric Permittivity	Relative Magnetic Permeability
1	Formation	s	0.00	5.80	1.00
3	Fiberglass cover of the sonde	s	0.00	4.70	1.00
6	Air near the driving point	s	0.00	1.00	1.00
7	Plastic cover of the driving point	s	0.00	3.70	1.00
10	Driving point and the cylindrical conductors	pc	∞	---	---

Table 2. Dimensions of regions 1, 3, 6, 7, and 10 in model 1 (Figure 1). Each region has a different shape, and so the number of coordinates needed to describe that shape generally varies.

Region 1		Region 3		Region 6		Region 7		Region 10	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.00000	-30.00000	0.00000	-0.48490	0.00200	-0.00510	0.03810	0.08100	0.00000	-0.47980
0.00000	-0.48490	0.00000	-0.47980	0.00570	-0.00510	0.00570	0.00510	0.03810	-0.47980
0.04320	-0.48490	0.03810	-0.47980	0.00570	0.00510	0.00570	-0.00510	0.03810	-0.08100
0.04320	0.48490	0.03810	0.47980	0.00200	0.00510	0.03810	-0.08100	0.00570	-0.00510
0.00000	0.48490	0.00000	0.47980					0.00200	-0.00510
0.00000	30.00000	0.00000	0.48490					0.00200	0.00510
30.00000	30.00000	0.04320	0.48490					0.00570	0.00510
30.00000	-30.00000	0.04320	-0.48490					0.03810	0.08100
								0.03810	0.47980
								0.00000	0.47980

Table 3. Coaxial cable used in model 1 (Figure 1). Type "s" refers to a region with standard or typical electromagnetic properties. Type "pc" refers to a region that is a perfect conductor. For such a region, both the relative dielectric permittivity and the relative magnetic permeability have no significance; consequently, the associated table entries are leaders (---). The dimensions are listed in Table 4.

Region Number	Description	Type	Electrical Conductivity (S/m)	Relative Dielectric Permittivity	Relative Magnetic Permeability
27	Inner Conductor	pc	∞	---	---
28	Dielectric Sheath	s	0.00	1.30	1.00
29	Outer Conductor	pc	∞	---	---

Table 4. Dimensions of the coaxial cable used for model 1 (Figure 1).

Region 27		Region 28		Region 29	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.00000	-0.02910	0.00200	-0.02910	0.00520	-0.02910
0.00000	-0.00510	0.00200	-0.00510	0.00520	-0.00510
0.00200	-0.00510	0.00520	-0.00510	0.00550	-0.00510
0.00200	-0.02910	0.00520	-0.02910	0.00550	-0.02910

MODEL 2

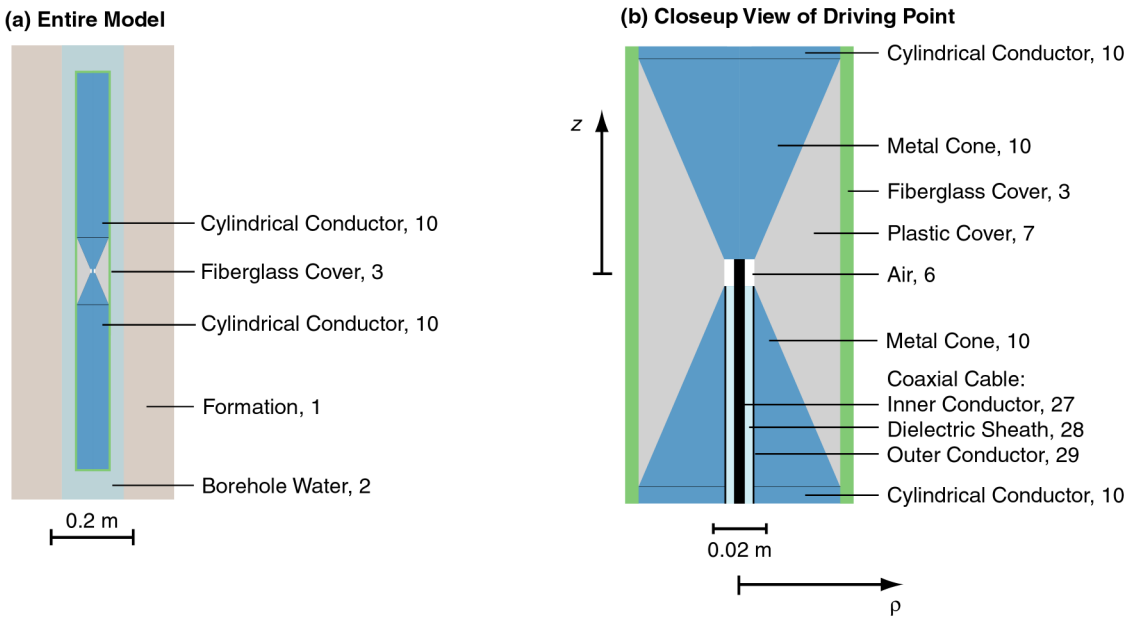

Figure 2. Model 2. Both diagrams are to scale and may be compared to the diagrams in Figures 1, 3, and 4. Each region of the model is referenced by a number. The electromagnetic properties and the dimensions of each region are listed in Tables 5 through 9.

Table 5. Regions of model 2, except for the coaxial cable (Figure 2). Type "s" refers to a region with standard or typical electromagnetic properties. Type "pc" refers to a region that is a perfect conductor. For such a region, both the relative dielectric permittivity and the relative magnetic permeability have no significance; consequently, the associated table entries are leaders (---). The dimensions of the regions are listed in Tables 6 and 7.

Region Number	Description	Type	Electrical Conductivity (S/m)	Relative Dielectric Permittivity	Relative Magnetic Permeability
1	Formation	s	0.00	5.80	1.00
2	Water in borehole	s	0.00	81.00	1.00
3	Fiberglass cover of the sonde	s	0.00	4.70	1.00
6	Air near the driving point	s	0.00	1.00	1.00
7	Plastic cover of the driving point	s	0.00	3.70	1.00
10	Driving point and the cylindrical conductors	pc	∞	---	---

Table 6. Dimensions of regions 1, 2, 3, 6, and 7 in model 2 (Figure 2). Each region has a different shape, and so the number of coordinates needed to describe that shape generally varies.

Region 1		Region 2		Region 3		Region 6		Region 7	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.07500	-30.00000	0.07500	-30.00000	0.00000	-0.48490	0.00200	-0.00510	0.03810	0.08100
0.07500	30.00000	0.07500	30.00000	0.00000	-0.47980	0.00570	-0.00510	0.00570	0.00510
30.00000	30.00000	0.00000	30.00000	0.03810	-0.47980	0.00570	0.00510	0.00570	-0.00510
30.00000	-30.00000	0.00000	0.48490	0.03810	0.47980	0.00200	0.00510	0.03810	-0.08100
		0.04320	0.48490	0.00000	0.47980				
		0.04320	-0.48490	0.00000	0.48490				
		0.00000	-0.48490	0.04320	0.48490				
		0.00000	-30.00000	0.04320	-0.48490				

Table 7. Dimensions of region 10 in model 2 (Figure 2).

Region 10	
ρ (m)	z (m)
0.00000	-0.47980
0.03810	-0.47980
0.03810	-0.08100
0.00570	-0.00510
0.00200	-0.00510
0.00200	0.00510
0.00570	0.00510
0.03810	0.08100
0.03810	0.47980
0.00000	0.47980

Table 8. Coaxial cable used in model 2 (Figure 2). Type "s" refers to a region with standard or typical electromagnetic properties. Type "pc" refers to a region that is a perfect conductor. For such a region, both the relative dielectric permittivity and the relative magnetic permeability have no significance; consequently, the associated table entries are leaders (---). The dimensions are listed in Table 9.

Region Number	Description	Type	Electrical Conductivity (S/m)	Relative Dielectric Permittivity	Relative Magnetic Permeability
27	Inner Conductor	pc	∞	---	---
28	Dielectric Sheath	s	0.00	1.30	1.00
29	Outer Conductor	pc	∞	---	---

Table 9. Dimensions of the coaxial cable used for model 2 (Figure 2).

Region 27		Region 28		Region 29	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.00000	-0.02910	0.00200	-0.02910	0.00520	-0.02910
0.00000	-0.00510	0.00200	-0.00510	0.00520	-0.00510
0.00200	-0.00510	0.00520	-0.00510	0.00550	-0.00510
0.00200	-0.02910	0.00520	-0.02910	0.00550	-0.02910

MODEL 3

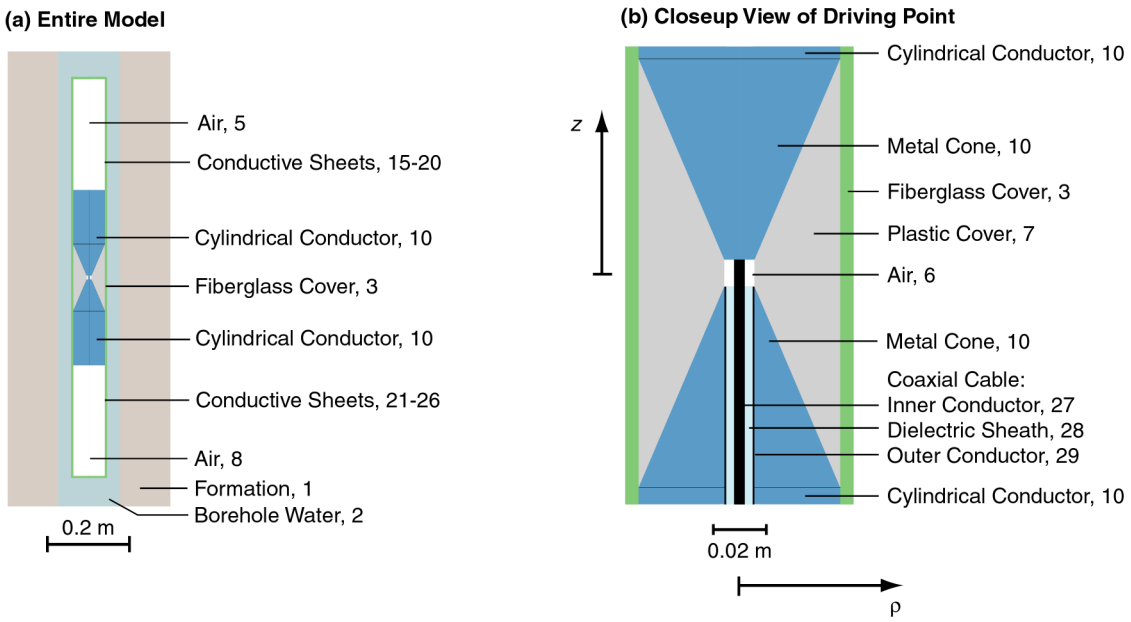

Figure 3. Model 3. Both diagrams are to scale and may be compared to the diagrams in Figures 1, 2, and 4. Each region of the model is referenced by a number. The electromagnetic properties and the dimensions of each region are listed in Tables 10 through 16.

Table 10. Regions of model 3, except for the coaxial cable (Figure 3). Type "s" refers to a region with standard or typical electromagnetic properties. Type "pc" refers to a region that is a perfect conductor. For such a region, both the relative dielectric permittivity and the relative magnetic permeability have no significance; consequently, the associated table entries are leaders (---). Type "cs" refers to a conductive sheet that is used to simulate the resistive loading on the antenna. The dimensions of the regions are listed in Tables 11 through 14.

Region Number	Description	Type	Electrical Conductivity (S/m)	Relative Dielectric Permittivity	Relative Magnetic Permeability
1	Formation	s	0.00	5.80	1.00
2	Water in borehole	s	0.00	81.00	1.00
3	Fiberglass cover of the sonde	s	0.00	4.70	1.00
5	Air behind the upper conductive sheets	s	0.00	1.00	1.00
6	Air near the driving point	s	0.00	1.00	1.00
7	Plastic cover of the driving point	s	0.00	3.70	1.00
8	Air behind the lower conductive sheets	s	0.00	1.00	1.00
10	Driving point and the cylindrical conductors	pc	∞	---	---
15	1st conductive sheet, upper Region of antenna	cs	75.16	4.70	1.00
16	2nd conductive sheet, upper Region of antenna	cs	64.43	4.70	1.00
17	3rd conductive sheet, upper Region of antenna	cs	52.44	4.70	1.00
18	4th conductive sheet, upper Region of antenna	cs	41.00	4.70	1.00
19	5th conductive sheet, upper Region of antenna	cs	25.05	4.70	1.00
20	6th conductive sheet, upper Region of antenna	cs	14.09	4.70	1.00
21	1st conductive sheet, lower Region of antenna	cs	75.16	4.70	1.00
22	2nd conductive sheet, lower Region of antenna	cs	64.43	4.70	1.00
23	3rd conductive sheet, lower Region of antenna	cs	52.44	4.70	1.00
24	4th conductive sheet, lower Region of antenna	cs	41.00	4.70	1.00
25	5th conductive sheet, lower Region of antenna	cs	25.05	4.70	1.00
26	6th conductive sheet, lower Region of antenna	cs	14.09	4.70	1.00

Table 11. Dimensions of regions 1, 2, 3, 5, and 6 in model 3 (Figure 3). Each region has a different shape, and so the number of coordinates needed to describe that shape generally varies.

Region 1		Region 2		Region 3		Region 5		Region 6	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.07500	-30.00000	0.07500	-30.00000	0.00000	-0.48490	0.00000	0.21180	0.00200	-0.00510
0.07500	30.00000	0.07500	30.00000	0.00000	-0.47980	0.03802	0.21180	0.00570	-0.00510
30.00000	30.00000	0.00000	30.00000	0.03810	-0.47980	0.03802	0.47980	0.00570	0.00510
30.00000	-30.00000	0.00000	0.48490	0.03810	0.47980	0.00000	0.47980	0.00200	0.00510
		0.04320	0.48490	0.00000	0.47980				
		0.04320	-0.48490	0.00000	0.48490				
		0.00000	-0.48490	0.04320	0.48490				
		0.00000	-30.00000	0.04320	-0.48490				

Table 12. Dimensions of regions 7, 8, 10, 15, and 16 in model 3 (Figure 3). Each region has a different shape, and so the number of coordinates needed to describe that shape generally varies.

Region 7		Region 8		Region 10		Region 15		Region 16	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.03810	0.08100	0.00000	-0.21180	0.00000	-0.21180	0.03802	0.21180	0.03802	0.25500
0.00570	0.00510	0.03802	-0.21180	0.03810	-0.21180	0.03802	0.25500	0.03802	0.29820
0.00570	-0.00510	0.03802	-0.47980	0.03810	-0.08100	0.03810	0.25500	0.03810	0.29820
0.03810	-0.08100	0.00000	-0.47980	0.00570	-0.00510	0.03810	0.21180	0.03810	0.25500
				0.00200	-0.00510				
				0.00200	0.00510				
				0.00570	0.00510				
				0.03810	0.08100				
				0.03810	0.21180				
				0.00000	0.21180				

Table 13. Dimensions of regions 17 to 21 in model 3 (Figure 3).

Region 17		Region 18		Region 19		Region 20		Region 21	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.03802	0.29820	0.03802	0.34140	0.03802	0.38460	0.03802	0.42770	0.03802	-0.21180
0.03802	0.34140	0.03802	0.38460	0.03802	0.42770	0.03802	0.47980	0.03802	-0.25500
0.03810	0.34140	0.03810	0.38460	0.03810	0.42770	0.03810	0.47980	0.03810	-0.25500
0.03810	0.29820	0.03810	0.34140	0.03810	0.38460	0.03810	0.42770	0.03810	-0.21180

Table 14. Dimensions of regions 22 to 26 in model 3 (Figure 3).

Region 22		Region 23		Region 24		Region 25		Region 26	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.03802	-0.25500	0.03802	-0.29820	0.03802	-0.34140	0.03802	-0.38460	0.03802	-0.42770
0.03802	-0.29820	0.03802	-0.34140	0.03802	-0.38460	0.03802	-0.42770	0.03802	-0.47980
0.03810	-0.29820	0.03810	-0.34140	0.03810	-0.38460	0.03810	-0.42770	0.03810	-0.47980
0.03810	-0.25500	0.03810	-0.29820	0.03810	-0.34140	0.03810	-0.38460	0.03810	-0.42770

Table 15. Coaxial cable used in model 3 (Figure 3). Type "s" refers to a region with standard or typical electromagnetic properties. Type "pc" refers to a region that is a perfect conductor. For such a region, both the relative dielectric permittivity and the relative magnetic permeability have no significance; consequently, the associated table entries are leaders (---). The dimensions are listed in Table 16.

Region Number	Description	Type	Electrical Conductivity (S/m)	Relative Dielectric Permittivity	Relative Magnetic Permeability
27	Inner Conductor	pc	∞	---	---
28	Dielectric Sheath	s	0.00	1.30	1.00
29	Outer Conductor	pc	∞	---	---

Table 16. Dimensions of the coaxial cable used for model 3 (Figure 3).

Region 27		Region 28		Region 29	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.00000	-0.02910	0.00200	-0.02910	0.00520	-0.02910
0.00000	-0.00510	0.00200	-0.00510	0.00520	-0.00510
0.00200	-0.00510	0.00520	-0.00510	0.00550	-0.00510
0.00200	-0.02910	0.00520	-0.02910	0.00550	-0.02910

MODEL 4

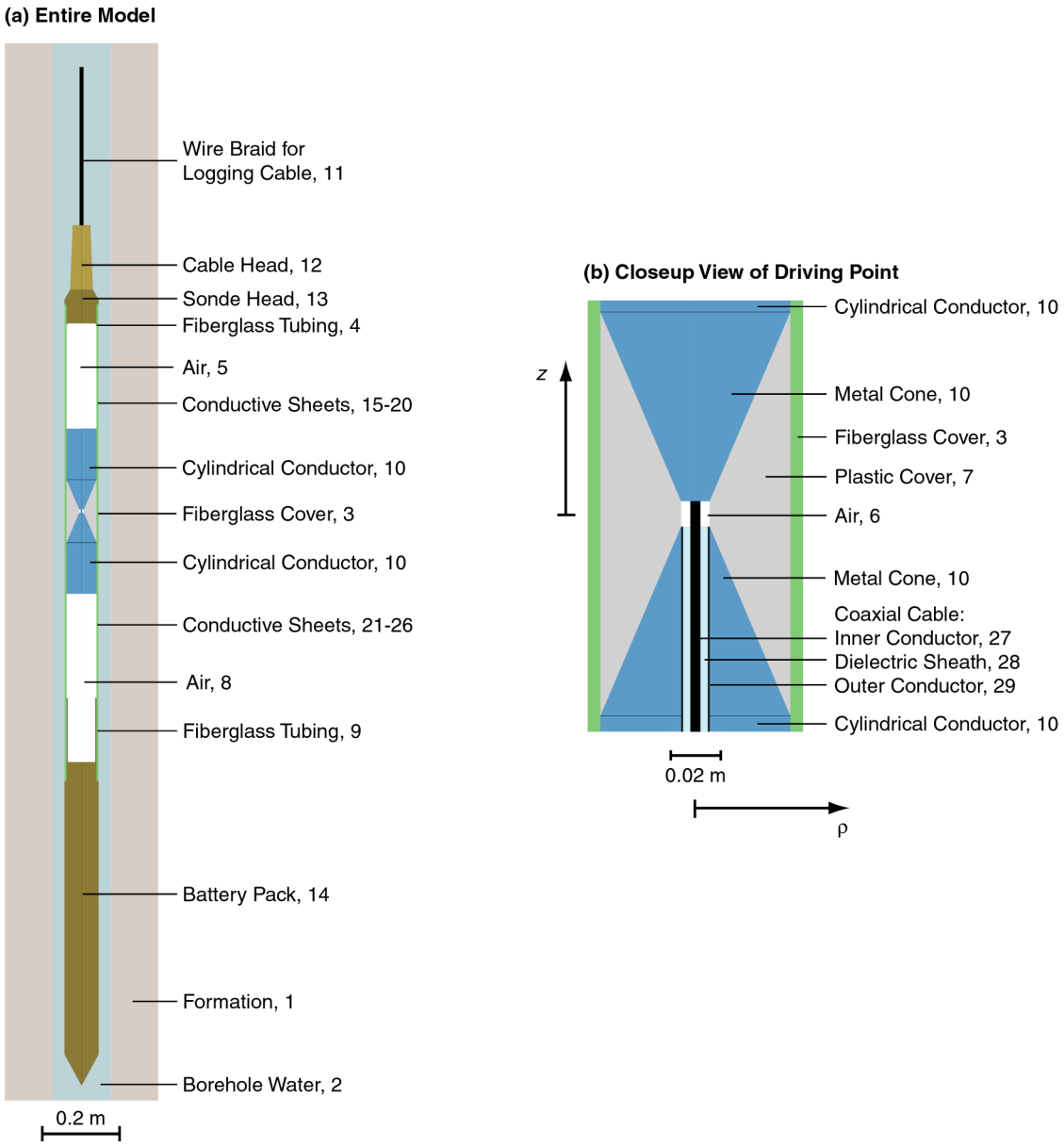

Figure 4. Model 4. Both diagrams are to scale and may be compared to the diagrams in Figures 1, 2, and 3. Each region of the model is referenced by a number. The electromagnetic properties and the dimensions of each region are listed in Tables 17 through 25.

Table 17. Regions of model 4, except for the coaxial cable (Figure 4). Type "s" refers to a region with standard or typical electromagnetic properties. Type "pc" refers to a region that is a perfect conductor. For such a region, both the relative dielectric permittivity and the relative magnetic permeability have no significance; consequently, the associated table entries are leaders (---). Type "cs" refers to a conductive sheet that is used to simulate the resistive loading on the antenna. The dimensions of the regions are listed in Tables 18 through to 23.

Region Number	Description	Type	Electrical Conductivity (S/m)	Relative Dielectric Permittivity	Relative Magnetic Permeability
1	Formation	s	0.00	5.80	1.00
2	Water in borehole	s	0.00	81.00	1.00
3	Fiberglass cover of the sonde	s	0.00	4.70	1.00
4	Fiberglass tubing near the sonde head	s	0.00	4.70	1.00
5	Air behind the upper conductive sheets	s	0.00	1.00	1.00
6	Air near the driving point	s	0.00	1.00	1.00
7	Plastic cover of the driving point	s	0.00	3.70	1.00
8	Air behind the lower conductive sheets	s	0.00	1.00	1.00
9	Fiberglass tubing near the battery pack	s	0.00	4.70	1.00
10	Driving point and the cylindrical conductors	pc	∞	---	---
11	Wire braid for logging cable	pc	∞	---	---
12	Cable head	pc	∞	---	---
13	Sonde head	pc	∞	---	---
14	Battery pack	pc	∞	--	---
15	1st conductive sheet, upper Region of antenna	cs	75.16	4.70	1.00
16	2nd conductive sheet, upper Region of antenna	cs	64.43	4.70	1.00
17	3rd conductive sheet, upper Region of antenna	cs	52.44	4.70	1.00
18	4th conductive sheet, upper Region of antenna	cs	41.00	4.70	1.00
19	5th conductive sheet, upper Region of antenna	cs	25.05	4.70	1.00
20	6th conductive sheet, upper Region of antenna	cs	14.09	4.70	1.00
21	1st conductive sheet, lower Region of antenna	cs	75.16	4.70	1.00
22	2nd conductive sheet, lower Region of antenna	cs	64.43	4.70	1.00
23	3rd conductive sheet, lower Region of antenna	cs	52.44	4.70	1.00
24	4th conductive sheet, lower Region of antenna	cs	41.00	4.70	1.00
25	5th conductive sheet, lower Region of antenna	cs	25.05	4.70	1.00
26	6th conductive sheet, lower Region of antenna	cs	14.09	4.70	1.00

Table 18. Dimensions of regions 1 to 5 in model 4 (Figure 4). Each region has a different shape, and so the number of coordinates needed to describe that shape generally varies.

Region 1		Region 2		Region 3		Region 4		Region 5	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.07500	-30.00000	0.07500	-30.00000	0.03810	0.53060	0.03560	0.47980	0.00000	0.21180
0.07500	30.00000	0.07500	30.00000	0.04320	0.53060	0.03810	0.47980	0.03810	0.21180
30.00000	30.00000	0.00000	30.00000	0.04320	-0.69370	0.03810	0.48230	0.03810	0.47980
30.00000	-30.00000	0.00000	1.14020	0.03810	-0.69370	0.03560	0.48230	0.03560	0.47980
		0.00480	1.14020					0.03560	0.48230
		0.00480	0.73380					0.00000	0.48230
		0.02220	0.73380						
		0.02860	0.56870						
		0.04320	0.54330						
		0.04320	-1.39550						
		0.00000	-1.47370						
		0.00000	-30.00000						

Table 19. Dimensions of regions 6 to 10 in model 4 (Figure 4). Each region has a different shape, and so the number of coordinates needed to describe that shape generally varies.

Region 6		Region 7		Region 8		Region 9		Region 10	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.00200	-0.00510	0.03810	0.08100	0.00000	-0.21180	0.03560	-0.47980	0.00000	-0.21180
0.00570	-0.00510	0.00570	0.00510	0.00000	-0.64490	0.03810	-0.47980	0.03810	-0.21180
0.00570	0.00510	0.00570	-0.00510	0.03560	-0.64490	0.03810	-0.64490	0.03810	-0.08100
0.00200	0.00510	0.03810	-0.08100	0.03560	-0.47980	0.03560	-0.64490	0.00570	-0.00510
				0.03810	-0.47980			0.00200	-0.00510
				0.03810	-0.21180			0.00200	0.00510
								0.00570	0.00510
								0.03810	0.08100
								0.03810	0.21180
								0.00000	0.21180

Table 20. Dimensions of regions 11 to 15 in model 4 (Figure 4). Each region has a different shape, and so the number of coordinates needed to describe that shape generally varies.

Region 11		Region 12		Region 13		Region 14		Region 15	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.00000	0.73380	0.00000	0.56870	0.00000	0.48230	0.00000	-1.47470	0.03802	0.21180
0.00480	0.73380	0.02860	0.56870	0.03810	0.48230	0.04320	-1.39550	0.03802	0.25500
0.00480	1.14020	0.02220	0.73380	0.03810	0.53060	0.04320	-0.69370	0.03810	0.25500
0.00000	1.14020	0.00000	0.73380	0.04320	0.53060	0.03810	-0.69370	0.03810	0.21180
				0.04320	0.54330	0.03810	-0.64490		
				0.02860	0.56870	0.00000	-0.64490		
				0.00000	0.56870				

Table 21. Dimensions of regions 16 to 30 in model 4 (Figure 4).

Region 16		Region 17		Region 18		Region 19		Region 20	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.03802	0.25500	0.03802	0.29820	0.03802	0.34140	0.03802	0.38460	0.03802	0.42770
0.03802	0.29820	0.03802	0.34140	0.03802	0.38460	0.03802	0.42770	0.03802	0.47980
0.03810	0.29820	0.03810	0.34140	0.03810	0.38460	0.03810	0.42770	0.03810	0.47980
0.03810	0.25500	0.03810	0.29820	0.03810	0.34140	0.03810	0.38460	0.03810	0.42770

Table 22. Dimensions of regions 21 to 25 in model 4 (Figure 4).

Region 21		Region 22		Region 23		Region 24		Region 25	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.03802	-0.21180	0.03802	-0.25500	0.03802	-0.29820	0.03802	-0.34140	0.03802	-0.38460
0.03802	-0.25500	0.03802	-0.29820	0.03802	-0.34140	0.03802	-0.38460	0.03802	-0.42770
0.03810	-0.25500	0.03810	-0.29820	0.03810	-0.34140	0.03810	-0.38460	0.03810	-0.42770
0.03810	-0.21180	0.03810	-0.25500	0.03810	-0.29820	0.03810	-0.34140	0.03810	-0.38460

Table 23. Dimensions of region 26 in model 4 (Figure 4).

Region 26	
ρ (m)	z (m)
0.03802	-0.42770
0.03802	-0.47980
0.03810	-0.47980
0.03810	-0.42770

Table 24. Coaxial cable used in model 4 (Figure 4). Type “s” refers to a region with standard or typical electromagnetic properties. Type “pc” refers to a region that is a perfect conductor. For such a region, both the relative dielectric permittivity and the relative magnetic permeability have no significance; consequently, the associated table entries are leaders (---). The dimensions are listed in Table 25.

Region Number	Description	Type	Electrical Conductivity (S/m)	Relative Dielectric Permittivity	Relative Magnetic Permeability
27	Inner Conductor	pc	∞	---	---
28	Dielectric Sheath	s	0.00	1.30	1.00
29	Outer Conductor	pc	∞	---	---

Table 25. Dimensions of the coaxial cable used for model 4 (Figure 4).

Region 27		Region 28		Region 29	
ρ (m)	z (m)	ρ (m)	z (m)	ρ (m)	z (m)
0.00000	-0.02910	0.00200	-0.02910	0.00520	-0.02910
0.00000	-0.00510	0.00200	-0.00510	0.00520	-0.00510
0.00200	-0.00510	0.00520	-0.00510	0.00550	-0.00510
0.00200	-0.02910	0.00520	-0.02910	0.00550	-0.02910