MDipole

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Document Versions:

01.00	Nov. 10, 2013	first draft
02.00	Feb. 26, 2014	more features
03.00	April 24, 2014	introduced view planes

References:

[1] Balanis, C. A.; Advanced Engineering Electromagnetics; John Wiley & Sons Inc. 2012

[2] Mc Tavish, J. P.; Field pattern of a magnetic dipole; Am. J. Phys. Vol. 68, No. 6, June 2000; pg. 577-578

[3] Mc Tavish, J. P.; Erratum: "Field pattern of a magnetic dipole" [Am. J. Phys. 68, 577-578 (2000)]; Am. J. Phys. 69, 1112 (2001)

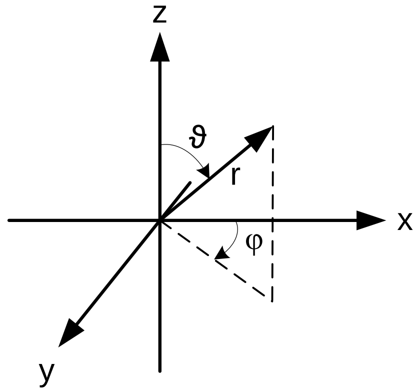
1 Introduction

The transmitting antenna of an avalanche transceiver is a magnetic dipole. The shape of the magnetic field created by a dipole is of interest for optimizing transceiver search procedures. `MDipole.exe` is a utility for exploring the properties of a magnetic dipole.

2 The Theory Behind

2.1 The Coordinate System

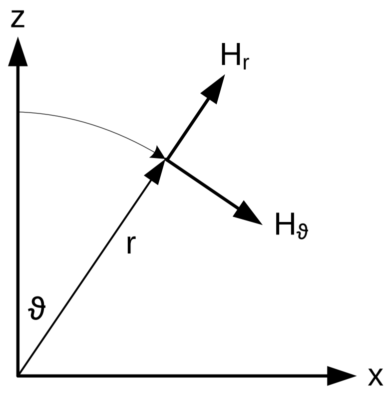
Since the H field of a magnetic dipole exhibits rotational symmetry about the axis of the dipole, it is of advantage to express the formulae for calculating the H field components in a spherical coordinate system:



Since there is rotational symmetry about the z axis, the φ components of the magnetic field will be 0.

2.2 The H Field Equations

The H field components are expressed in terms of H_r and H_ϑ:



The equations that define the H field are [1]:

$$H_r = \frac{M}{2\pi \bullet r^2} \bullet \left[1 + \frac{1}{jkr}\right] \bullet \cos(\vartheta) \bullet e^{-jkr}$$

$$H_\vartheta = j \bullet \frac{M \bullet k}{4\pi \bullet r} \bullet \left[1 + \frac{1}{jkr} - \frac{1}{(kr)^2}\right] \bullet \sin(\vartheta) \bullet e^{-jkr}$$

where M is the magnetic moment and $k = 2\pi / \lambda$ is the wave number.

In air, λ is 656.001 meters at 457.000 kHz, and so k amounts to 0.009578.

Since M and e^{-jkr} are equal for both components, the above equations can be re-written without loss of generality:

$$H_r = \frac{1}{2\pi} \bullet \left[\frac{1}{r^2} - j\frac{1}{kr^3}\right] \bullet \cos(\vartheta)$$

$$H_\vartheta = j \bullet \frac{1}{4\pi} \bullet \left[\frac{k}{r} + j\frac{1}{r^2} - \frac{1}{kr^3}\right] \bullet \sin(\vartheta)$$

It can be easily seen that at distances close to the dipole ($r << \frac{1}{k}$), H_r at $r = r0, \vartheta = 0$ will be double the value of H_ϑ at $r = r0, \vartheta = 90^o$.

2.3 H Field Lines

2.3.1 H Field

For drawing the H field lines, `MDipole` uses the solution to the differential equation in Cartesian coordinates:

$$\frac{dy}{dx} = \frac{2y^2 - x^2}{3xy}$$

The solution to this equation has been published by Mc Tavish [2]:

$$x^2 + y^2 = Cx^{\frac{4}{3}} \quad \text{or} \quad y = \sqrt{Cx^{\frac{4}{3}} - x^2}$$

2.3.2 Equal Potential

The lines of equal potential are orthogonal to the H field lines. So their differential equation is

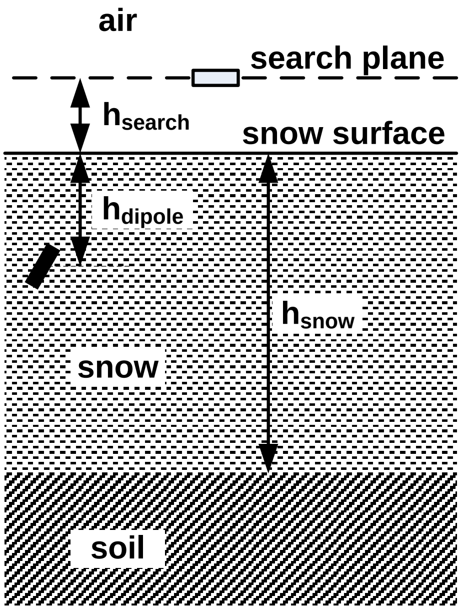
$$\frac{dy}{dx} = -\frac{3xy}{2y^2 - x^2}$$

This equation can be solved in an analogous way to give:

$$x^2 + y^2 = Cy^{\frac{2}{3}} \qquad \text{or} \qquad x = \sqrt{Cy^{\frac{2}{3}} - y^2}$$

2.4 The Layer Model

Where applicable, we use the following layer model:



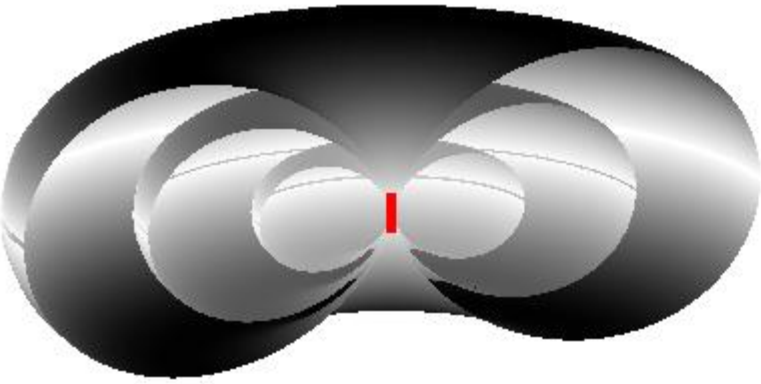
All layers are assumed to have the same dielectric and magnetic properties, i.e. $\varepsilon_r = 1.0$, $\sigma = 0.0$ and $\mu_r = 1.0$. In reality, for snow and soil, those are different from the values for air. The dielectric properties of snow depend heavily on snow porosity, grain shape and size, water content and temperature. The dielectric properties of soil are also quite variable, mostly due to water content and temperature.

At distances < 10 meters, the influence of the actual layer properties is marginal and can be neglected for most purposes. At large distances, usually > 20 m, there is some influence on the shape of the field lines above the snow surface. But its effects on a transceiver search are also minimal. This has been verified by means of a real 3 layer simulation using the Finite Difference Time Domain (FDTD) algorithm, using various parameter settings for snow and for soil.

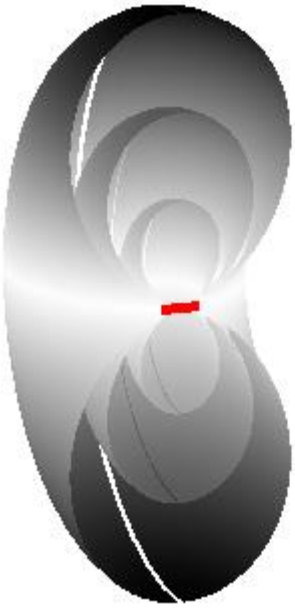
3 The Shape of the Dipole Field

For vertical and horizontal dipoles, the three-dimensional shape is as follows:

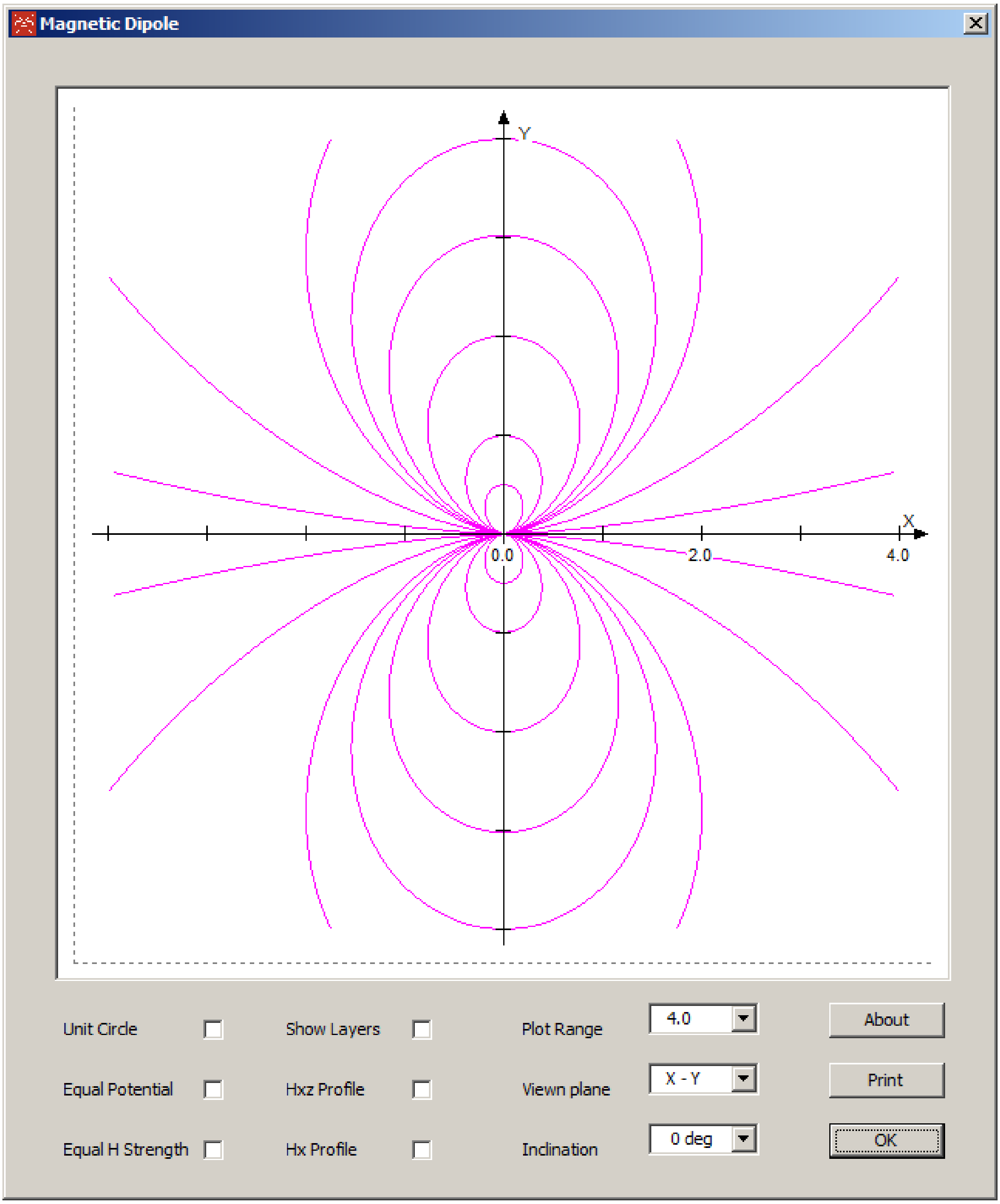
3.1 Vertical Dipole



3.2 Horizontal Dipole



4 User Interface



Per default, the program shows the H field lines of a horizontal magnetic dipole which is centered at the intersection of the x and y axes. Depending on the selected view plane, additional features may be made visible:

4.1 Both Planes

4.1.1 Unit Circle

A unit circle can be made to show. This can help in taking some measurements.

4.1.2 Plot Range

The default plot range is 4 units. It may be set to other values ranging from 1 to 64 units, depending on the range of interest.

4.2 X – Y Plane

The X-Y plane is a horizontal plane at the elevation of the magnetic dipole.

4.2.1 Equal Potential

An example of an equal potential line is shown in blue. This curve is only available for 0 deg inclination.

4.2.2 Equal H Strength

The equal H surface around a magnetic dipole is not a perfect sphere. The cross section of the equal H surface is shown in green. This curve is only valid for an inclination of 0º. This curve is only available for 0 deg inclination.

4.2.3 Inclination

This is the angle between the horizontal plane and the dipole axis. The inclination of the dipole axis relative to the horizontal plane may be set from 0 to 90 degrees in increments of 15 degrees. The lines shown are the projections of the field lines of the inclined dipole onto the horizontal X-Y plane.

4.3 X – Z Plane

The X-Z plane is a vertical plane; it represents a cross-section at the center of the magnetic dipole.

4.3.1 Show Layers

A typical layer configuration is overlaid with a cross section of the H field at the dipole axis. The search height and the burial depth are set to 1 m, and the snow layer depth is set to 3 m.

4.3.2 Hxz Profile

This is the magnitude of the H field on a line 1 m above the snow surface. It corresponds to the H field sensed by a 3 antenna device that is held horizontally at the search height.

4.3.3 Hx Profile

This is the magnitude of the x component of the H field on a line 1 m above the snow surface. It corresponds to the H field sensed by a device with no third (vertical) antenna that is held horizontally at the search height.

4.3.4 Inclination

This is the angle between the horizontal plane and the dipole axis. The inclination of the dipole axis relative to the horizontal plane may be set from 0 to 90 degrees in increments of 15 degrees. The lines shown are the field lines of the inclined dipole in the cross-section plane.

4.4 Cursors

A horizontal and a vertical cursor are parked to the left and at the bottom. The cursors can be dragged to any place inside the display. Cursors will only show on the printout when out of their parking position.

4.5 H field Values

In order to display the H field value at a certain location, place the cursor at the location and press the left mouse key.

If you want to display H field values on top of a cursor line, place the cursor a little distance from the line, press the left mouse key and then move the cursor to the point of interest. If you press the left mouse button while the cursor is on top of a line, the cursor line will be selected for dragging.

In the X-Y plane, H filed values are only available for 0 degrees of inclination.

H field values are not absolute values, the represent values for M = 1. Evidently, the real value of M depends on the electronics of the transceiver.