ROTATING DIPOLES

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Block Diagram

Figure 1 shows the breakdown of the coded system as a block diagram. In the plant section, the electric field of the dipole system is calculated based on the original values for charges, angular speed and acceleration, distance between charges, and distance of the observer from the system. The x and y components of the field are then applied to the sensor which iterates the field over time. The values are then outputted to different plots showing the position of the dipoles, magnitude of the electric field at given times, and the oscillation of the field over time. The controller consists of scroll bars on the 2D plot of the electric field over time allowing the values of the system to be changed. Here the user is able to force the dipoles to converge and watch how the system changes. The changed values are then applied to the plant and the system starts again with the altered values.

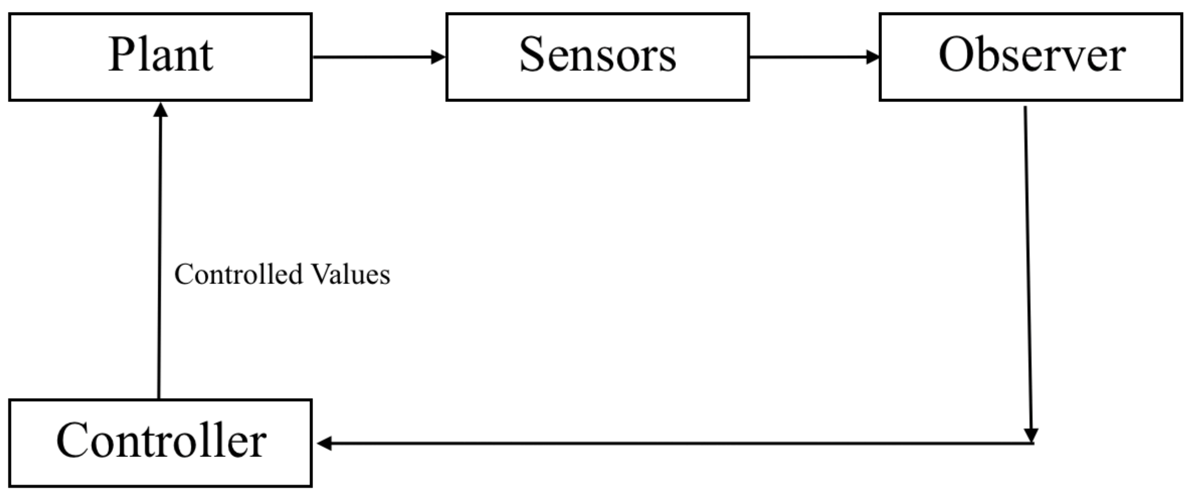

Figure 1 – Block diagram of system showing the how the data proceeds through the system.

Equations of Motion

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\ (r\ direction) \quad (1)$$

Where E is the electric field of a point charge in N/C, ε_0 is the permittivity of free space ($1.257 \times 10^{-6}\ H/m$), q is the charge of a point charge, and r is the distance from the charge to the point of observation.

$$E = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_+^2}(r_+ direction) - \frac{q_2}{r_-^2}(r_- direction)\right) \quad (2)$$

Where E is the total electric field of a two-dipole system at observing point, r_+ is the distance of the observer from the positive charge, and r_- is the distance of the observer from the negative charge.

$$r_+^2 = d^2 + r_0^2 - 2dr_0\cos(\theta) \quad (3)$$

$$r_-^2 = d^2 + r_0^2 - 2dr_0\cos(180° - \theta) \quad (4)$$

Where r_0 is the distance from the center of the dipole system to the observer, d is half the distance from one charge to the other (distance to the center), and θ is the angle between observer and the positive charge in degrees.

$$p(t) = p_0[\cos(\omega t)\, E_y + \sin(\omega t)\, E_x] \quad (5)$$

$$p_0 = q * d \quad (6)$$

Where $p(t)$ is the electric field of a rotating dipole over time (N/C), p_0 is the magnitude of the dipole (Cm), ω is the angular velocity of the rotating system, t is the time (s), E_y is the electric field in the y-direction (N/C), and E_x is the electric field in the x-direction (N/C).

Methods

Implementation

In order to implement the observer, the equations used for calculating electric field (equations 1 and 2) incorporated the distance from a point experiencing the electric field. By breaking these distances down into constant components reliant on the angle with the observing point (shown in equations 3 and 4), the distance from the observer to the center of the dipole as well as the distance between the charges were identified. To implement the controller, scroll bars were added to the two-dimensional plot with the electric field on the y-axis and time on the x-axis. The bars allow the user the ability to change the components of the system. This way the controller could force the dipoles to converge as the system attempts to mimic the 2 black hole system converging.

Validation

In order to validate the rotating dipole system, calculations of the electric field were taken at different points in time to see if they matched that of the system output from a constant observing point. These values were calculated under the assumption that the system was not rotating fast enough to produce electromagnetic waves. Additionally, when the system converges, it was expected that the dipoles would cancel, however, an overall magnitude of electric field would remain. This is proven in Figure 4 where two graphs show a zero dipole, but the contour lines show one center over time.

Plots

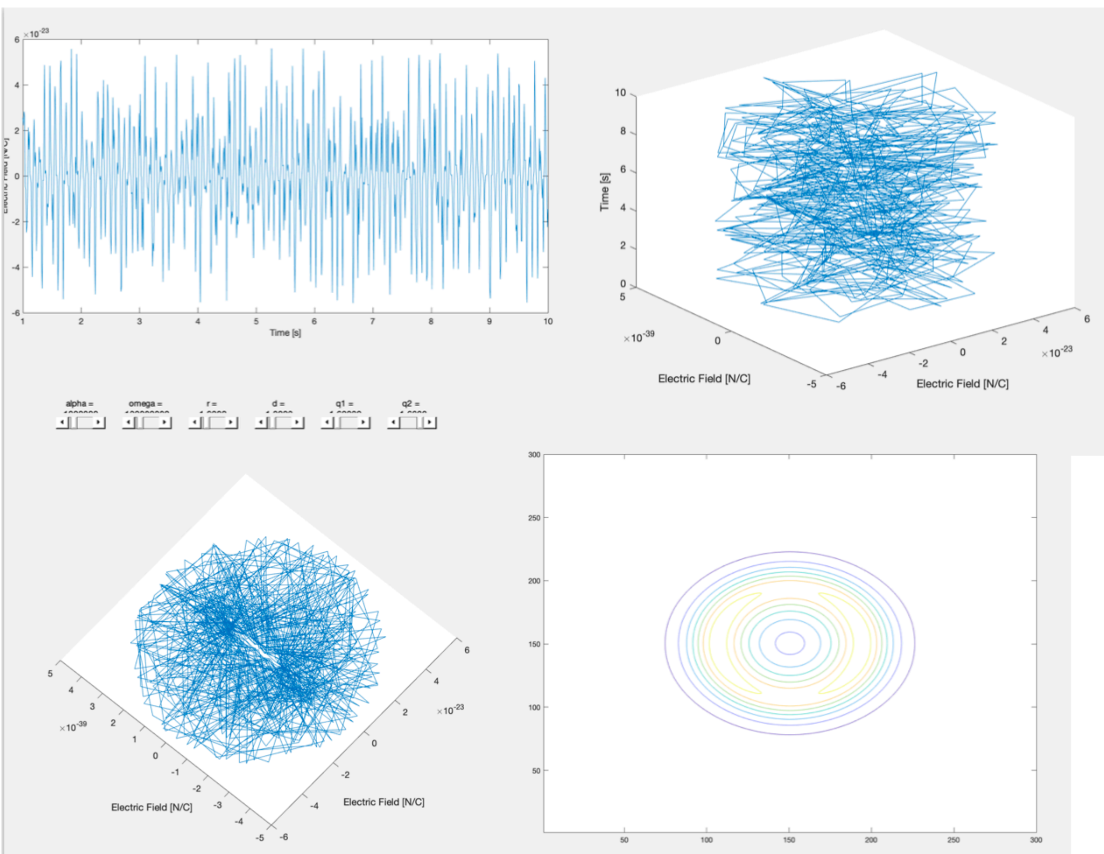

Figure 2 – Plots of observed and controller states. Top left graph shows the magnitude of the electric field from an observing point, r_0, as time progresses on the x-axis. Top right and bottom left show the 3D plot of the electric field in x and y directions

with where the field is focused around. The bottom right plot shows the electric field over a given area. Distance between the dipoles is 100x10^-12 m (standard starting point for simulation).

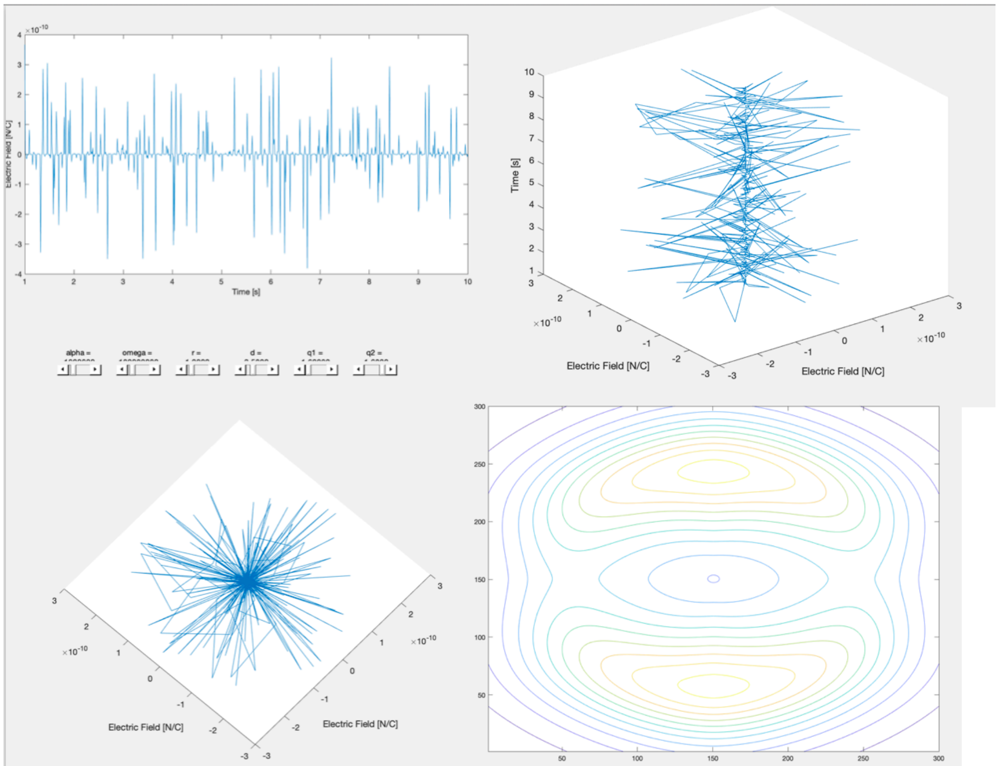

Figure 3 – Plots of observed and controller states. Top left graph shows the magnitude of the electric field from an observing point, r_0, as time progresses on the x-axis. Top right and bottom left show the 3D plot of the electric field in x and y directions with where the field is focused around. The bottom right plot shows the electric field over a given area. Distance between the dipoles is 2.50x10^-10 m (changed following controller adjustment).

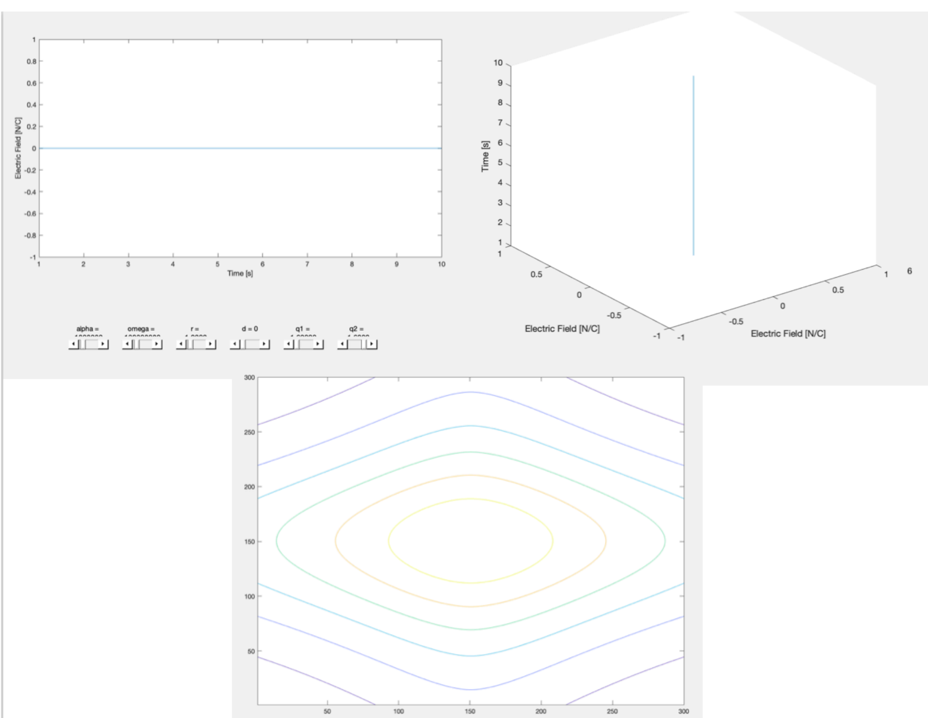

Figure 4 – Plots of observed and controller states. Top left graph shows the magnitude of the electric field from an observing point, r_0, as time progresses on the x-axis. Top right shows the 3D plot of the electric field in x and y directions. The bottom plot shows the magnitude of the electric field over a given area after convergence (dipoles converged from control system).

References

[1] J. Jackson, Simple Radiating Systems, 11 May 2010. [Online]. Available: http://www.tat.physik.uni-tuebingen.de/~kokkotas/Teaching/Field_Theory_files/FT_course04.pdf.