Lab #2 – Rayleigh Fading Simulation

In this lab you will simulate the effects of Rayleigh Fading by creating three-dimensional plots of the electric field in MATLAB. From these plots you will collect statistics on the signal envelope, and see whether the samples fit a Rayleigh distribution or not.

Section 1: Visualizing a TEM wave in MATLAB

To help guide the latter portions of this lab, it is helpful to begin with a single Transverse mode Electro-Magnetic (TEM) wave. If the TEM wave is propagating in the direction of the x-axis, a mathematical equation describing the electric field can be written as

$$\vec{E}(t) = E_o \cdot \cos(\omega_c t - k_0 x + \phi) \cdot \hat{a}_z$$

$$\text{where } k_0 = \text{wave number} = \frac{2\pi}{\lambda}$$

Shown below is a two-dimensional plot of the electric field for a frequency of 300 MHz (wavelength $\lambda = 1$m), and phase $\phi = 0$. The plot is constructed with the x-axis as distance, showing the spatial variation of the electric field. The different plots capture the electric field at different points in time, and show the wave propagation in the x-direction.
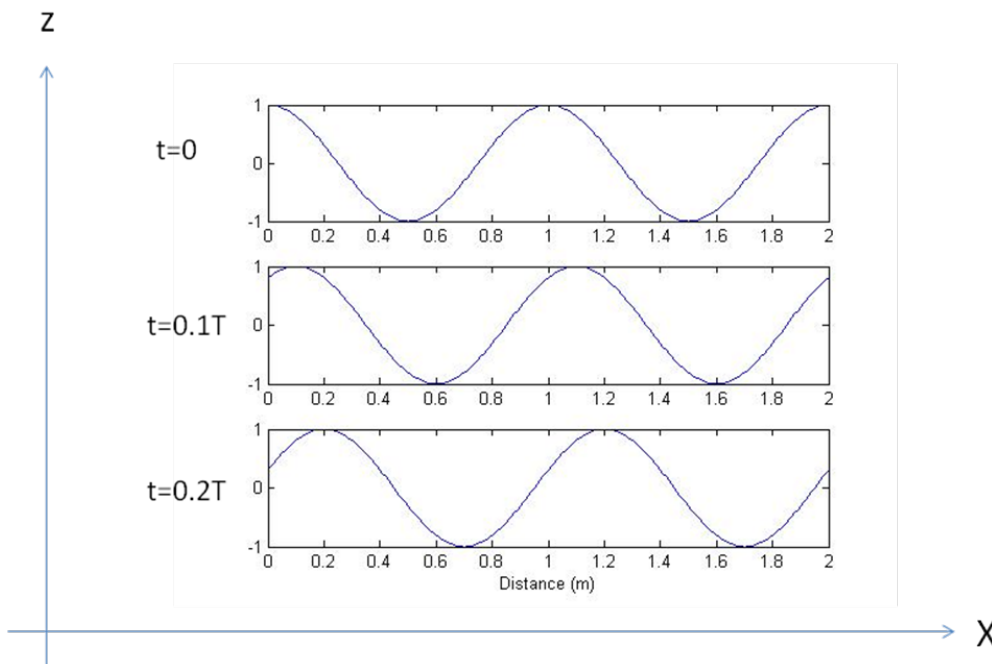
Your first task in this lab is to construct a three-dimensional plot of the electric field propagating in the x-direction. The EM wave is vertically polarized, meaning that the E-field vector is parallel to the z-axis. In MATLAB, the **surf** function will create three-dimensional surface plots. You are welcome to experiment with the color and lighting of your surface plot, although I have found that these settings produce decent results:

surf (X,Y,Z, 'FaceColor', 'red', 'EdgeColor', 'none')

camlight left

lighting phong

The coordinate system of the MATLAB surface plot is as shown:
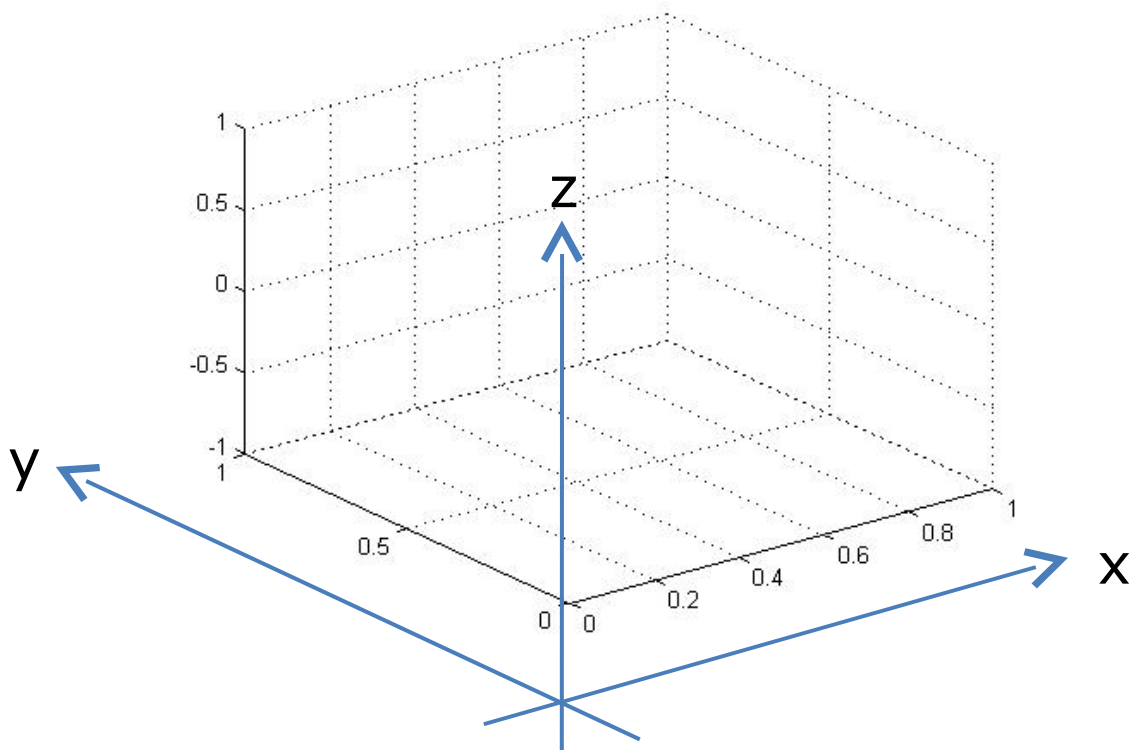
The following parameter should be used:

Frequency f_c = 900 MHz, T = $1/f_c$

The size of the plot is 3 wavelengths in the x-direction, and 3 wavelengths in the y-direction. At a frequency of 900 MHz, this should result in a 1m x 1m box as shown above. You may find the MATLAB function **meshgrid** helpful here.

Run the plot from t = 0 to t = T, in steps of 0.05T. By having MATLAB redraw in the same window, this will have the effect of animation, showing the EM wave propagate in the x-direction.
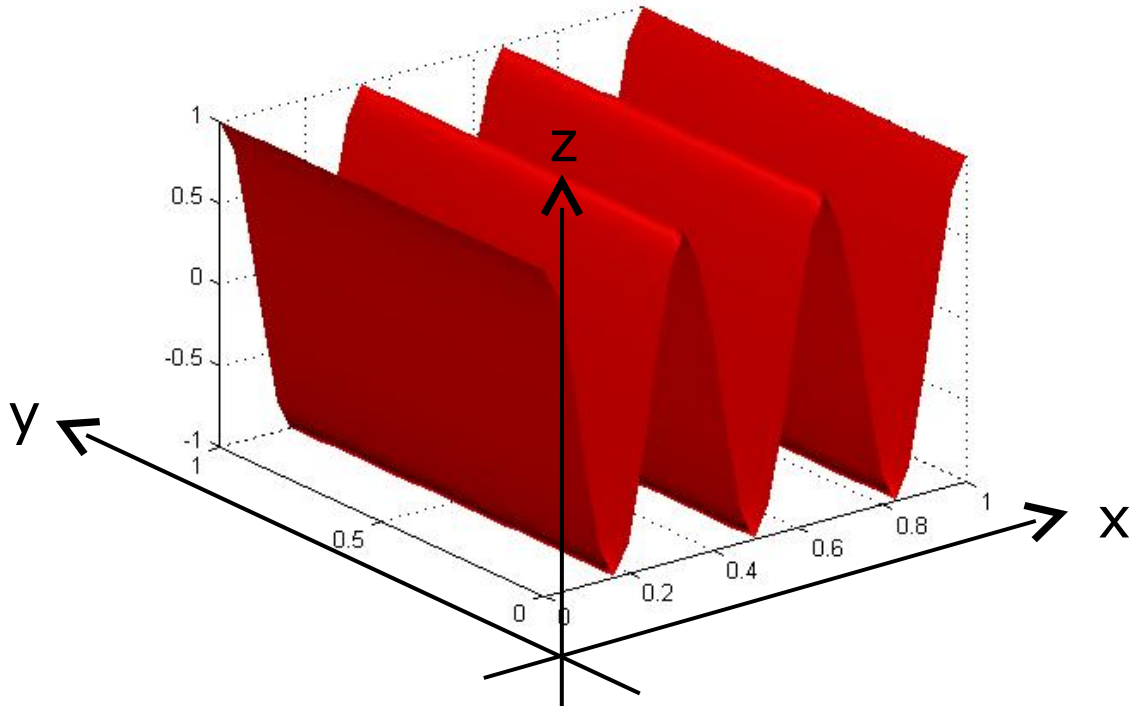
After confirming with the instructor that your code is working, make a modification such that the EM wave can propagate along any direction in the x-y plane. (ie. the direction of propagation is a vector lying in the x-y plane, forming an angle θ with the x-axis). The EM wave is still vertically polarized.

$$\vec{E}(t) = E_o \cdot \cos(\omega_c t - k_o(x \cdot \cos\theta + y \cdot \sin\theta) + \phi) \cdot \hat{a}_z$$

Again, check your result with the instructor before proceeding to the next section.

Section 2: Multipath Fading

Recall that when an area is cluttered with many objects, an EM wave can reflect off the different surfaces and take multiple paths to arrive at a given point. Depending on the

relative phase of the arriving rays, constructive or destructive interference can occur. The case where there is no LOS path or dominant ray is called Rayleigh fading.

Using your code from Section 1, begin by constructing <u>ten</u> EM waves / rays and summing them up over the 3λ x 3λ grid. The amplitude, direction, and phase of the rays shall be random.

Amplitude E_o : uniformly distributed over [0.5, 1]

Direction θ : uniformly distributed over [0, 2π]

Phase ϕ : uniformly distributed over [0, 2π]

Just like before, animate the MATLAB simulations by stepping it through a set of time points, and observe how the interference patterns evolve.

In a typical radio, the receiver is only sensitive to the power or RMS value of the signal. In other words, what matters is the magnitude of the signal, and not the sign. Collect magnitude samples from the 3λ x 3λ grid and construct a histogram. Observe the statistical distribution and relate it to the theory covered in class.

Repeat the above by experimenting with the number of rays (at least one case with less than 10 rays, and one case with more than 10 rays). How is the statistical distribution affected?

Hand in a lab report by no later than the beginning of the next lab.