California State University, Bakersfield

ECE 3320 – Fields and Waves

Lab 5 – Wave Propagation

Introduction: All electromagnetic waves can be represented as a simple sinusoidal waveform. In this lab we will simulate different waveforms and their interactions with each other using MATLAB.

A standing wave is a waveform that has a constant phase, thus is dependent only on frequency. The equation for a standing wave is $y(\text{t}) = A\cos(\omega t+\theta)$ where A is the amplitude of the wave, ω is the angular frequency and θ is the phase offset.

However, we are interested in traveling waveforms. A traveling wave can be represented as a standing wave with a varying phase. This can be represented as $y(t, x) = A\cos(\omega t+\beta x+\phi_0)$ where β is the phase constant and ϕ_0 is the reference angle. If $\beta > 0$, then the wave is traveling in the negative x-direction. If $\beta < 0$, then the wave is traveling in the positive x-direction.

Procedure:

1. Open MATLAB.

2. Make a new script file. This can be done by clicking the "HOME" tab at the top and clicking on new script. Name and save your file.

3. Create an array, x, with 100 points. Starting from 1 up to 100.

4. Create variables representing:

   $\lambda = 10$

   $f = 1$

   $A = 1$

   $\beta = 2\pi/\lambda$

   $\omega = 2\pi f$

5. Create a for loop that loops for a variable, i, from 100 to 1000 in n steps. (choose an appropriate step size)

6. In the loop set t=0.1*i. This will be your time step.

7. In the loop, write the equation $y = A*\cos(\omega*t-\beta*x)$ and plot the graph using plot(x, y). This will generate new graph every iteration depending on the current value of t. In order to slow the graph, use pause(0.1). You can alter this command to change the simulation speed. NOTE: To stop the simulation, go to the command window and press “Ctrl+C”.

8. Change values of frequency and wavelength and observe the changes. How does each effect the graph?

9. Create a new sine wave with traveling in the opposite direction. Plot both waves on the same graph.

10. Change the frequency of the second wave and plot.

11. Plot the sum of the two waves on the same plot. You may want to use the axis command to constrain the limits of the graph. What happens to the sum when the two waves are 180° out of phase? What happens when the two waves are in phase?

Next we will consider wave dispersion.

12. Remove the sum of the two waves, and the second wave. Change the equation to the form

$y = Ae^{-\alpha x}\cos(\omega t-\beta x)$ where α is the attenuation constant of the wave. Set α = 0.01 and plot the graph. What happens to the waveform as the wave propagates?

13. Graph $Ae^{-\alpha x}$, $Ae^{-\alpha x}$, and $-Ae^{-\alpha x}\cos(\omega t-\beta x)$ on the same plot. You should see that the wave decays at the same rate as the exponential graphs. These exponential functions are the envelope of the waveform.

Include graphs and code in your report.