UNIVERSITY OF UTAH
ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

ECE1020 **COMPUTING ASSIGNMENT 2**
N. E. COTTER
MATLAB® SCRIPT FILES AND MATHEMATICAL EXPRESSIONS

READING
Matlab® Student Version: learning Matlab 6, Ch 4.10-4.16
Mastering Matlab® 6, Ch 4

TOPICS
.m Script Files
Anntena radiation pattern calculation

OVERVIEW
This assignment is the first part of what will be the design of a complete (simulated) communication link. This link is similar to that used by your cell phone, or by satellite to ground communications, or by a base station sending instructions to a remote vehicle. For the sake of illustration, we will assume our communication link is being used to control a robotic vehicle like the Mars rover. The link has several components:

1) Antenna
2) Receiver filters
3) Quantizer
4) Decoding of error-correction code

The goal of the communication system is to send binary information—ones and zeros—to the robot vehicle while protecting those bits from noise that might arise from, for example, sun spots or solar flares. With the error-correction code, we add redundancy and spread bits out over time. Thus, we send a different set of bits than the set of bits we ultimately want to communicate, and we send more bits than we ultimately want to communicate.

When bits are sent from the base station to the robot vehicle, we use an antenna to receive radio waves that encode bits as short waveforms at high frequencies. For the antenna design, we determine a frequency and antenna length that maximizes the power in the signal received by the robot vehicle. The noise from interfering sources adds to the received signal and can change a one or zero into a number between one and zero. If we round off the values to one or zero, noise that is large enough can change a one to a zero or vice versa. If we maximize the power received from the antenna, we increase the signal relative to the noise and reduce the chances of making an error.

The antenna output feeds a filter that translates received waveforms into ones and zeros. We will design the filter to optimally discriminate ones and zeros. We then quantize the filter output to decide whether each bit is a one or zero.

The last step in the communication system design is to determine which code words were sent and translate them back into the corresponding binary strings. We do this by calculating the distance from the received binary strings and each of the possible codewords in our codebook. We will design this codebook later on.

PROCEDURE

You will calculate an antenna reception pattern in this assignment. The reception pattern is the same as the radiation pattern, [1]. The formula we use is adapted from the formula for a linear wire antenna appearing in [2]. To make such an antenna, we start with parallel wires and bend the last length, ℓ, of the wires away from each other at right angles to the rest of the wire. The resulting shape is like a "T" where the stem is the pair of parallel wires, and the top of the T is the ends of the wires that form the antenna. Note that the top of the T, or the antenna, has length 2ℓ plus the distance between the parallel wires, which we ignore.

The formula for the antenna reception pattern is rather complicated. Consequently, it is subdivided into smaller equations defining terms that we combine to form larger expressions. In Matlab, we can define variables corresponding to each equation and containing appropriate numerical values that we combine to get our final answer.

+60 pts Script File for antenna radiation calculation

Using a simple text editor such as the Notepad program on your PC or the editor in Matlab®, create a script file called Pavecalc.m containing matlab commands to perform the calculations corresponding to the equations below starting with $\mu_0 = 4\pi \cdot 10^{-7}$. Assume a variable called 'theta' already exists for θ. Put one command or comment on each line of the file, and type them exactly like you would type them into Matlab. Put your name on the first line as a comment, e.g. % Neil Cotter.

Save Pavecalc.m on drive c: (at the top level, not in a sub-directory, unless you make corresponding changes to the cd command later on). Translate symbols such as β_0 into Matlab variable names such as beta0. Be careful not to use variable names that are part of Matlab. For example, beta is a Matlab function. (Type

>> help beta

to see that Matlab has a definition for beta.) Also note that Matlab ignores capital letters in variable names. You may use them for clarity, but be careful not to create two variables that are the same name when capitals are ignored.

$\mu_0 = 4\pi \cdot 10^{-7}$	% (H/m) permeability of vacuum
$\varepsilon_0 = 8.854 \cdot 10^{-12}$	% (F/m) permittivity (dielectric const.) of vacuum
$r = 100$	% (m) distance between transmitter and receiver
$\ell = 0.5$	% (m) half-length of antenna
$\omega = 2\pi \cdot 10^{8}$	% (rad/s) frequency of radio waves
$I_0 = 1 \cdot 10^{-3}$	% (A) magnitude of current in antenna
$\eta_0 = \sqrt{\mu_0 / \varepsilon_0}$	% (Ω) intrinsic wave impedance
$\beta_0 = \omega\sqrt{\mu_0 \varepsilon_0}$	% (m-1) propagation constant
$\square = \frac{1}{8\pi^2} \frac{\lvert I_0 \rvert^2}{\sin^2(\beta_0 \ell)} \frac{\eta_0}{r^2}$	% (W/m^2) power per area constant
$F_\theta = \left[\frac{\cos(\beta_0 \ell \cos\theta) - \cos(\beta_0 \ell)}{\sin\theta} \right]^2$	% unitless angular radiation pattern factor
$P_{ave} = \square F_\theta$	% (W/m2) antenna radiation at angle θ

+5 pts Diary Command
When you have finished typing the script file for the above equations, delete the current diary file and start a new diary.
>>diary on % turns on diary

+5 pts Change Working Directory
Change the working directory to the c: drive where you stored your script file.
This an alternative to the addpath command if everything you write is stored in one directory.
>> cd c:\

+5 pts Set the value of θ to $\pi/6$ radians (i.e., 30°). We will be calculating the power received by our antenna given the angle relative to the transmitter.
>>theta = pi/6

+10 pts Run Script File
Run your script file by typing the name of the file without the .m
>> Pavecalc
Paste the calculated value of Pave into a file called recvdata.m for plotting later on. (You should get 3.4404e-11.)
If you make any changes in your Pavecalc.m file, be sure to run the following Matlab command to insure that Matlab reads your file again the next time you run it:
>> clear all

+10 pts Repeat Calculations
Try theta values that are multiples of pi/6 up to theta = 2*pi. (If you get an error such as a divide by zero, try changing the value of theta by 0.01.) This will give you an idea of the reception pattern of the antenna.

+5 pts End of Diary
>> diary off % Close the diary file. Look for the diary in e.g., c:\matlab\work directory.

E-mail your script file (Pavecalc.m), your data file (recvdata.m), and your diary file to your TA, (as three separate e-mails). In the Subject line of your e-mail, be sure to put Your Name, "ECE1020 Comp2," and the file name, (e.g. Pavecalc.m). Also, print out the files and hand them in to the TA or the ECE1020 locker.

REFERENCES
[1] S. Ramo, J. R. Whinnery, T. Van Duzer, *Fields and Waves in Communication Electronics*. NY: John Wiley, 1965, p. 718.
[2] M. F. Iskander, *Electromagnetic Fields and Waves*. Prospect Hts, Illinois: Waveland Press, 1992, p. 662.