BioE2005 | Comp. Proj 1

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```matlab
function [epsilon] = newt(gamma_meas,trials,theta_i,alpha)
%% Newton's method
%   gamma_meas is how we compute first epsilon/guess
% we assume 0 degree incidence ==> theta_i = 0
%  theta_t = asin(sin0/sqrt(epsilon)) = asin(0) = 0
% ==> gamma_meas(1+sqrt(epsilon)) = 1-sqrt(epsilon)
% ==> gamma_meas + gamma_meas*sqrt(epsilon) = 1 - sqrt(epsilon)
% ==> sqrt(epsilon)(gamma_meas+1) = 1 - gamma_meas
x1 = ((1-gamma_meas)/(1+gamma_meas))^2; % initial guess
x2 = x1*1.05;
for trial=1:trials
    theta_t1 = asin(sin(theta_i)/(sqrt(x1)));
    theta_t2 = asin(sin(theta_i)/(sqrt(x2)));
    y1 = gamma_meas - (cos(theta_t1)-cos(theta_i)*sqrt(x1))/(cos(theta_t1)+cos(theta_i)*sqrt(x1));
    y2 = gamma_meas - (cos(theta_t2)-cos(theta_i)*sqrt(x2))/(cos(theta_t2)+cos(theta_i)*sqrt(x2));
    if (abs(y1)<alpha)
        epsilon = x1;
        break
    elseif (abs(y2)<alpha)
        epsilon = x2;
        break
    else
        x3 = abs(((x2-x1)*(-y1)/(y2-y1))+x1);
        x1 = x3; x2 = x3*1.05;
    end
end
end
```

MATLAB function to solve for the dielectric constant, `epsilon`, at any incident angle with any reflection coefficient, given those inputs as well as the tolerance (`alpha`) and number of `trials`

```
%% Arjan Singh Puniani
%% BIOE 2005 - Computer Proj 1
% we will be calculating the dielectric constant from experimentally
% measured reflection coefficients

%% method: newton
gammas = [-0.1 -0.5 -0.9];
alphas = [0.1 0.01 0.001 0.0001];
iterations = 100000000;
for i=1:numel(gammas)
    for j=1:numel(alphas)
        for theta_i=pi/9:pi/9:(4*pi/9)
            epsilon = newt(gammas(i),iterations,theta_i,alphas(j));
            disp("for gamma " + gammas(i) + " with alpha " + alphas(j))
            disp("our \epsilon at " + (180/pi)*theta_i + " is " + epsilon)
        end
    end
```

Loops through the possible incident angles in radians

For Γ= -0.1
and at
α=0.0001

for gamma -0.1 with alpha 0.1
our \epsilon at 20 is 1.4938
for gamma -0.1 with alpha 0.1
our \epsilon at 40 is 1.4938
for gamma -0.1 with alpha 0.1
our \epsilon at 60 is 3.3291
for gamma -0.1 with alpha 0.1
our \epsilon at 80 is 38.8378

for gamma -0.1 with alpha 0.01
our \epsilon at 20 is 1.5685
for gamma -0.1 with alpha 0.01
our \epsilon at 40 is 2.0006
for gamma -0.1 with alpha 0.01
our \epsilon at 60 is 4.8897
for gamma -0.1 with alpha 0.01
our \epsilon at 80 is 47.7153

for gamma -0.1 with alpha 0.001
our \epsilon at 20 is 1.5685
for gamma -0.1 with alpha 0.001
our \epsilon at 40 is 2.0269
for gamma -0.1 with alpha 0.001
our \epsilon at 60 is 5.0965
for gamma -0.1 with alpha 0.001
our \epsilon at 80 is 48.5645

for gamma -0.1 with alpha 0.0001
our \epsilon at 20 is 1.5654
for gamma -0.1 with alpha 0.0001
our \epsilon at 40 is 2.0269
for gamma -0.1 with alpha 0.0001
our \epsilon at 60 is 5.0965
for gamma -0.1 with alpha 0.0001
our \epsilon at 80 is 48.5645

MATLAB outputs

Error in experimental measurements

Used to find corresponding biological tissues

For Γ= -0.5 and at α=0.0001

for gamma -0.5 with alpha 0.01
our \epsilon at 20 is 10.0321
for gamma -0.5 with alpha 0.01
our \epsilon at 40 is 14.158
for gamma -0.5 with alpha 0.01
our \epsilon at 60 is 35.1055
for gamma -0.5 with alpha 0.01
our \epsilon at 80 is 288.459

for gamma -0.5 with alpha 0.1
our \epsilon at 20 is 9
for gamma -0.5 with alpha 0.1
our \epsilon at 40 is 9
for gamma -0.5 with alpha 0.1
our \epsilon at 60 is 21.9557
for gamma -0.5 with alpha 0.1
our \epsilon at 80 is 227.3798

for gamma -0.5 with alpha 0.001
our \epsilon at 20 is 10.0321
for gamma -0.5 with alpha 0.001
our \epsilon at 40 is 14.8674
for gamma -0.5 with alpha 0.001
our \epsilon at 60 is 35.1055
for gamma -0.5 with alpha 0.001
our \epsilon at 80 is 297.6

for gamma -0.5 with alpha 0.0001
our \epsilon at 20 is 10.0751
for gamma -0.5 with alpha 0.0001
our \epsilon at 40 is 14.9131
for gamma -0.5 with alpha 0.0001
our \epsilon at 60 is 35.2373
for gamma -0.5 with alpha 0.0001
our \epsilon at 80 is 297.6

MATLAB outputs

Error in experimental measurements

Used to find corresponding biological tissues

For Γ= -0.9 and at α=0.0001

for gamma -0.9 with alpha 0.1
our \epsilon at 20 is 361
for gamma -0.9 with alpha 0.1
our \epsilon at 40 is 361
for gamma -0.9 with alpha 0.1
our \epsilon at 60 is 361
for gamma -0.9 with alpha 0.1
our \epsilon at 80 is 2920.0709

for gamma -0.9 with alpha 0.01
our \epsilon at 20 is 361
for gamma -0.9 with alpha 0.01
our \epsilon at 40 is 538.4815
for gamma -0.9 with alpha 0.01
our \epsilon at 60 is 1195.0917
for gamma -0.9 with alpha 0.01
our \epsilon at 80 is 9818.3728

for gamma -0.9 with alpha 0.001
our \epsilon at 20 is 406.1546
for gamma -0.9 with alpha 0.001
our \epsilon at 40 is 610.2436
for gamma -0.9 with alpha 0.001
our \epsilon at 60 is 1419.1235
for gamma -0.9 with alpha 0.001
our \epsilon at 80 is 11748.0421

for gamma -0.9 with alpha 0.0001
our \epsilon at 20 is 408.7863
for gamma -0.9 with alpha 0.0001
our \epsilon at 40 is 614.9004
for gamma -0.9 with alpha 0.0001
our \epsilon at 60 is 1443.8161
for gamma -0.9 with alpha 0.0001
our \epsilon at 80 is 11975.9473

MATLAB outputs

Error in experimental measurements

Used to find corresponding biological tissues

		IFAC Dielectric Properties of Body Tissue							
alpha=0.00001		choice 1				choice 2			
Incident wave	Calculated relative permittivity	closest permittivity	frequency	tissue	% error	closest permittivity	frequency	tissue	% error
20	1.5654	error in experimental measurements							
40	2.0269								
60	5.0965	5.1347	2.5119 GHz	BreastFat	0.74%	5.1267	3.9811 GHz	Fat	0.59%
80	48.5645	48.811	2.5119 GHz	BrainGreyMatter	0.51%	48.292	2.5119 GHz	LungDeflated	0.56%
20	10.0751	10.44	39.811 GHz	Tendon	3.50%	10.542	39.811 GHz	Tooth	4.43%
40	14.9131	14.914	25.119 GHz	Nerve	0.01%	14.508	39.811 GHz	Cerebellum	2.79%
60	35.2373	35.43	398 MHz	Nerve	0.54%	34.587	10 GHz	Cerebellum	1.88%
80	297.6	293.47	100 MHz	Heart	1.41%	302.56	3.98 MHz	Trachea	1.64%
20	408.7863	432.88	3.981 MHz	Ovary	5.57%	386	3.98 MHz	Muscle	5.90%
40	614.9004	617.66	3.98 MHz	Oesophagus	0.45%	617.66	3.98 MHz	Duodenum	0.45%
60	1443.8161	1422.9	630 kHz	Lens	1.47%	1495.4	158 kHz	Ovary	3.45%
80	11975.9473	11683	10 kHz	Testis	2.51%	11683	10 kHz	Prostate	2.51%

Based on your results and other observations, provide a brief summary (one paragraph) regarding the behavior of the dielectric properties (specifically dielectric constant and conductivity) of different types of biological tissues as a function of frequency.

As you increase applied frequency, the dielectric constant/relative permittivity decreases, while the conductivity increases: $\omega\uparrow \Rightarrow \varepsilon\downarrow\sigma\uparrow$

This relationship seems most clear for fatty tissue, like the brain (due to myelination) or breast fat: the lowest relative permittivity corresponded to high frequency ranges (>GHz). The conductivities (not tabulated), tended to increase with applied frequency, almost suggesting that if you energize your RF waves (3 kHz – 300 GHz) sufficiently high, you can force tissue into becoming a better conductor.

For the larger calculated dielectric constants (in the 400 to 12,000 range), the tissues of comparable permittivity (e.g. testis ovaries) had lower corresponding applied frequencies (in the kHz to low MHz range) than those for brains and cerebellums.

Tissues can absorb energy (not from ***B*** but from ***E***). The amount of heating will depend on perfusion.