1. $\omega = 5.8\times10^{9}\cdot 2\pi = 11.6\pi\times10^{9}$

$T = 1/f = 1.7\times10^{-10}\ s$

$\varepsilon_r = 1.5 \qquad u = \frac{c}{\sqrt{\varepsilon_r}} = 2.45\times10^{8}\ m/s$

$\beta = \frac{\omega}{u} = 47.36\pi = 148.8$

$\lambda = .0422\ m$ also check $\lambda = \frac{u}{f} = .0422$

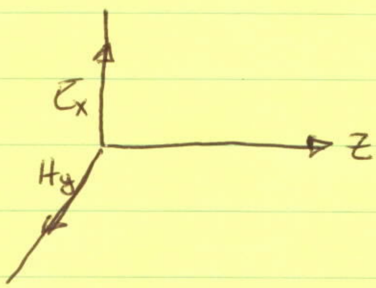
$\eta = \sqrt{\frac{\mu_0}{\varepsilon_r\varepsilon_0}} = \frac{1}{\sqrt{\varepsilon_r}}120\pi = 307.8\ \Omega$

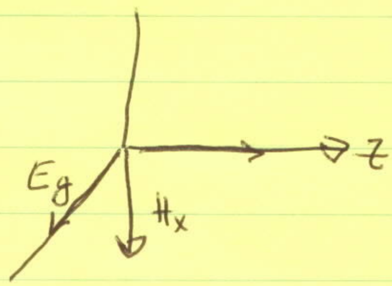
one polarization $E_x(z) = E_o e^{-j\beta z}$

$H_y(z) = \frac{E_o}{\eta} e^{-j\beta z}$

second polarization $E_y(z) = E_o e^{-j\beta z}$

$H_x(z) = -\frac{E_o}{\eta} e^{-j\beta z}$





Find E_o $\qquad \vec{E}\cdot\vec{E} = E_x^2 + E_y^2$

Ave Power Dens $= P = \frac{E_o^2}{2\eta} + \frac{E_o^2}{2\eta}$

$E_o^2 = 2\eta(.02\times10^{-3})(10^4)\ W/m^2$

$= 2\eta\ .2 = .4\eta$

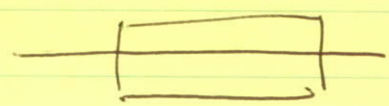
$E_o = \sqrt{.4\eta} = 11\ V/m$

Checking $\frac{1}{2}\frac{E_o^2}{\eta} = .2\ \frac{W}{m^2} = .02\ \frac{mW}{cm^2}$

$$E_x(z,t) = E_0 \cos(\omega t - \beta z)$$
$$H_y(z,t) = \frac{E_0}{\eta} \cos(\omega t - \beta z)$$
$$E_y(z,t) = E_0 \cos(\omega t - \beta z)$$
$$H_x(z,t) = -\frac{E_0}{\eta} \cos(\omega t - \beta z)$$

With the parallel plates, E_x is shorted out thus we only have the E_y

$$V(z) = E_y h$$



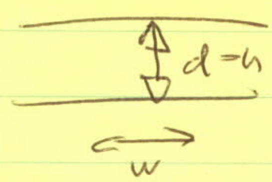
$$I(z) = \pm H_x W$$ depending on the plate

$$\frac{V}{I} = \frac{\eta E_0 e^{-j\beta z} h}{E_0 e^{-j\beta z} W} = \eta \frac{h}{W}$$

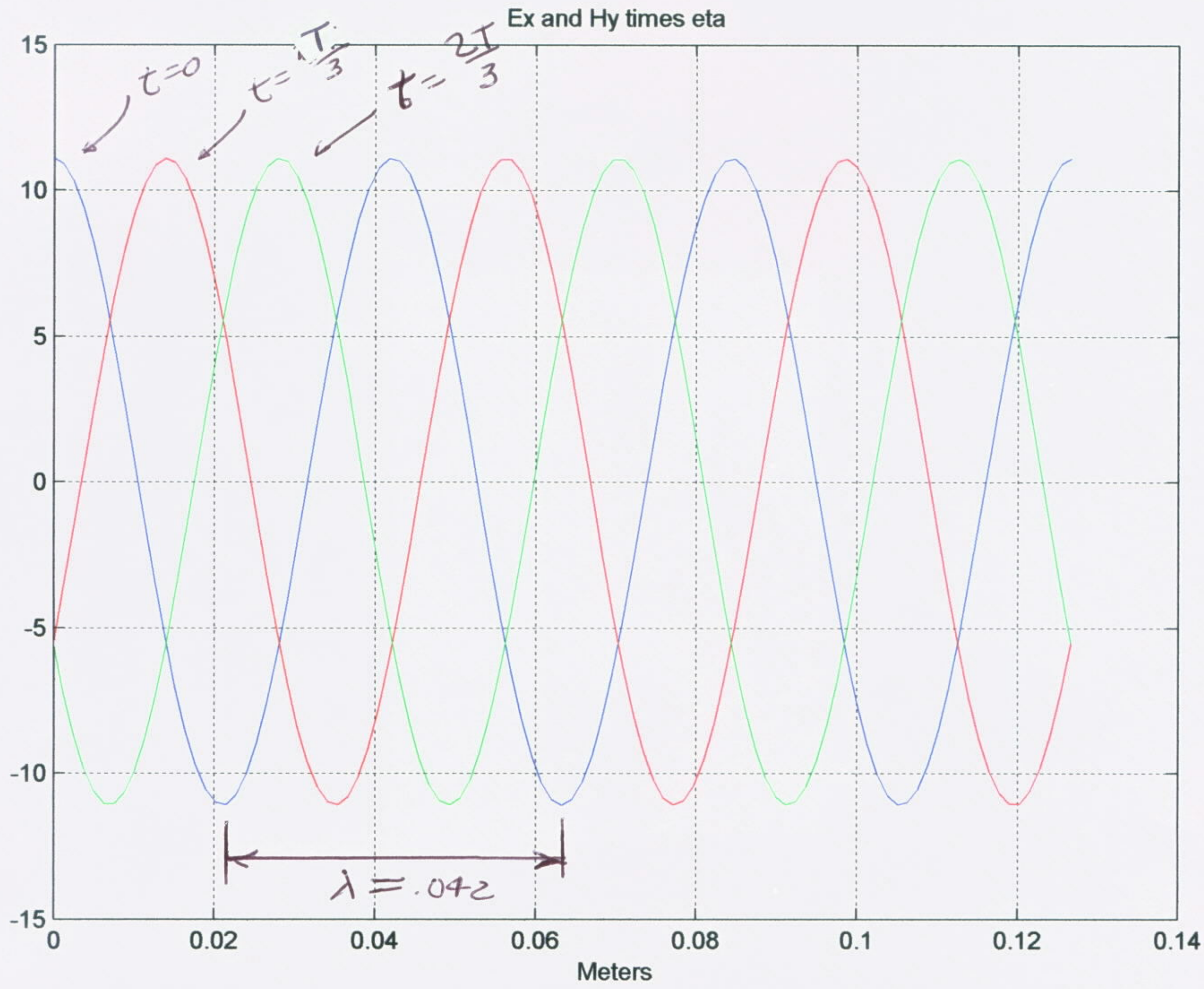
From many references $L = \mu \frac{d}{w}$ $C = \varepsilon \frac{w}{d}$

$$Z_0 = \sqrt{\frac{L}{C}} = \sqrt{\frac{\mu}{\varepsilon}\frac{d^2}{w^2}} = \sqrt{\frac{\mu}{\varepsilon}}\,\frac{d}{w}$$ where $d = h$

so this checks.



For the plotting of the waves E_x & H_y look the same except $E_x = \eta H_y$ so only one is plotted.



Ex and Hy times eta
15
10
5
0
-5
-10
-15
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
Meters
t=0
t= T/3
t= 2T/3
λ = .042

2. For turkey $\varepsilon = \varepsilon' - j\varepsilon''$

$\varepsilon_r' = 40 \quad \varepsilon_r'' = 14$

From Metaxas' paper.

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} = \frac{14}{40} = 0.35$$

$$\omega = 2\pi f = 4.9\pi \times 10^9 = 1.54 \times 10^{10}$$

$\alpha = 56$ using the exact expression
$= 56.8$ using the low loss diel

$\beta = 329.3$ using the exact expression
$= 324.5$ using the low loss diel

approx solution is OK for many purposes.

$$\lambda = \frac{2\pi}{\beta} = 0.019\, m$$

$$\eta_c = 57.1 - j\,9.7$$

$$u = \omega/\beta = 4.7 \times 10^7 \ m/s$$

Power absorbed is $\frac{1}{2} Re \int \bar{J} \cdot \bar{E}\, dv = \frac{1}{2} Re \left[\int \omega \varepsilon'' E^2 dv \right]$

$(E_0 e^{-\alpha z})^2$

$$= \frac{1}{2} \underbrace{(.1)(.1)}_{\text{area}} \int_0^{.1} \omega \varepsilon'' E_0^2 e^{-2\alpha z} dz$$

$$= \frac{1}{2} (.01)\, \omega \varepsilon'' E_0^2 \int_0^{.1} e^{-2\alpha z} dz$$

$$\int_0^{.1} e^{-2\alpha z}\,dz = -\frac{1}{2\alpha} e^{-2\alpha z}\Big|_0^{.1}$$

$$= \frac{1}{2\alpha}\left(1 - e^{-2\alpha \cdot .1}\right)$$

$$2\alpha \cdot .1 = 2 \cdot 56 \cdot .1 = 11.2$$

$$e^{-11.2} = 1.4\times10^{-5} \approx 0$$

$$\Rightarrow \quad \text{Power} = \frac{1}{2}(.01)\frac{(\omega\varepsilon'' E_0^2)}{2\alpha} = 300\,W$$

$$E_0^2 = \frac{4\alpha\, 300}{\omega\,\varepsilon''\,.01}$$

$$E_0 = 1.9\times10^3\ V/m$$

$$E_x = E_0\, e^{-\alpha z} e^{-j\beta z}$$

$$H_y = \frac{E_0}{\eta_c} e^{-\alpha z} e^{-j\beta z}$$

$$P_{ave} = \frac{1}{2}\,\mathrm{Re}\, E_x H_y^* = \frac{1}{2}\,\mathrm{Re}\,\frac{E_0^2}{\eta_c^*}$$

$$= 3.00\times10^4\ W/m^2$$

$$P_{ave} \times \underbrace{.01}_{\text{area of cube}} = 300 \text{ Watts}$$

which is exactly the same as 300 W as expected.

```
% Finding Wave Parameters in Lossy Media
% Only lossy dielectrics are considered, not conductors
% K. A. Connor 14 April 2007

% Frequency
f=2.45e9; w=2*pi*f;

% Materials
mu=4*pi*1e-7;
epso=(1/(36*pi))*1e-9;
epsr=40*epso;
epsi=14*epso;

% First the most general form for the propagation constants
% Alpha
alf=w*sqrt((mu*epsr/2)*(sqrt(1+(epsi/epsr)^2)-1));

% Beta
beta=w*sqrt((mu*epsr/2)*(sqrt(1+(epsi/epsr)^2)+1));

% Now the good conductor
% Alpha
alfc=w*sqrt(mu*epsi/2);

% Beta
betac=alfc;

% Finally the low loss dielectric
% Alpha
alfd=(w*epsi/2)*sqrt(mu/epsr);

% Beta
betad=w*sqrt(mu*epsr);

% Wavelength
lam=2*pi/beta;

% Intrinsic Impedance
eta=sqrt(mu/(epsr+i*epsi));

% Phase Velocity
u=w/beta;

% Power Delivered to a Cube of Turkey
P=300;
% Area of Cube
A=0.01;
% Amplitude of electric field
e0=sqrt((4*alf*P)/(w*epsi*A));
% Checking Power from Poynting Vector
PP=A*0.5*(e0^2)*real(1/conj(eta));
```

If you Run this you will see that the approximate solutions are quite accurate