EE 481/581 Microwave Engineering
Quiz #1 (Fall 2024)

Name Key A

Instructions: Open book & notes. Place answers in indicated spaces and show all work for credit.

At 2.4 GHz, a sample of non-magnetic Grubbium A has a measured loss tangent of 0.1 and relative permittivity of 2.4. Determine the complex permittivity ε_c and effective conductivity σ. Then, find the attenuation constant, phase constant, phase velocity, and intrinsic impedance seen by a plane wave propagating through Grubbium A. Put complex numbers in rectangular format.

non-mag.

$\tan\delta = 0.1 = \frac{\sigma}{\omega\epsilon'}$ $\quad \epsilon_r = \frac{\epsilon'}{\epsilon_0} = 2.4$ $\quad \mu = \mu_0$

$\epsilon' = \epsilon_r \epsilon_0 = 2.4(8.854187\,8\times10^{-12}) = 2.1250\times10^{-11}$ F/m

(Notes) $\epsilon'' = \epsilon' \tan\delta = (2.125\times10^{-11})(0.1) = 2.125\times10^{-12}$ F/m

$\epsilon_c = \epsilon' - j\epsilon'' =$ 21.25 − j 2.125 pF/m

eff. cond $\sigma = \omega\epsilon'' = 2\pi(2.4\times10^9)\,2.125\times10^{-12}$

$= 0.032044$ S/m

(1.52) $\gamma = \alpha + j\beta = j\omega\sqrt{\mu\epsilon'}\sqrt{1 - j\frac{\sigma}{\omega\epsilon}}$ ← loss tangent

$= j\,2\pi(2.4\times10^9)\sqrt{4\pi\times10^{-7}(2.125\times10^{-11})}\sqrt{1-j0.1}$

$= 3.89139385 + j\,78.02196\,27$ rad/m

(Table 1.1) $v_p = \omega/\beta = \frac{2\pi(2.4\times10^9)}{78.02196} = 1.9327436\times10^8$ m/s

(1.57) $\eta = \frac{j\omega\mu}{\gamma} = \frac{j\,2\pi(2.4\times10^9)4\pi\times10^{-7}}{3.8914 + j\,78.022}$

$= 242.27305 + j\,12.083519\ \Omega$

$\varepsilon_c =$ 21.25 − j 2.125 pF/m $\qquad \sigma =$ 0.032044 S/m

attenuation constant = 3.8914 Np/m $\qquad$ phase constant = 78.022 rad/m

phase velocity = 1.9327×10^8 m/s $\qquad$ intrinsic imped. = 242.273 + j 12.0835 Ω

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Name Key B

Instructions: Open book & notes. Place answers in indicated spaces and show all work for credit.

At 1.8 GHz, a sample of non-magnetic Grubbium B has a measured loss tangent of 0.08 and relative permittivity of 2.8. Determine the complex permittivity ε_c and effective conductivity σ. Then, find the attenuation constant, phase constant, phase velocity, and intrinsic impedance seen by a plane wave propagating through Grubbium B. Put complex numbers in rectangular format.

$\tan\delta = 0.08$, $\epsilon_r = 2.8 = \epsilon'/\epsilon_0$, $\mu = \mu_0$ (non-magnetic)

(Notes) $\epsilon' = \epsilon_r \epsilon_0 = 2.8(8.8541878\times10^{-12}) = 2.4791726\times10^{-11}$ F/m

$\epsilon'' = \epsilon' \tan\delta = 2.4792\times10^{-11}(0.08) = 1.983338\times10^{-12}$ F/m

$\epsilon_c = \epsilon' - j\epsilon'' = 24.792 - j\,1.983$ pF/m

eff. cond. $\sigma = \omega\epsilon'' = 2\pi(1.8\times10^9)(1.983338\times10^{-12})$

$= 0.022431$ S/m

(1.52) $\gamma = \alpha + j\beta = j\omega\sqrt{\mu\epsilon'}\sqrt{1 - j\sigma/\omega\epsilon'}$ ← loss tangent

$= j\,2\pi(1.8\times10^9)\sqrt{4\pi\times10^{-7}(2.8)8.8542\times10^{-12}}\sqrt{1-j0.08}$

$= 2.5230396 + j\,63.17675514$ 1/m

(Table 1.1) $v_p = \omega/\beta = \dfrac{2\pi(1.8\times10^9)}{63.17675} = 1.7901733\times10^8$ m/s

(1.57) $\eta = \dfrac{j\omega\mu}{\gamma} = \dfrac{j\,2\pi(1.8\times10^9)4\pi\times10^{-7}}{2.52304 + j\,63.17675}$

$= 224.6016 + j\,8.969735\ \Omega$

$\varepsilon_c =$ 24.792 − j1.983 pF/m $\sigma =$ 0.02243 S/m

attenuation constant = 2.523 Np/m phase constant = 63.17675 rad/m

phase velocity = 1.7902×10^8 m/s intrinsic imped. = 224.602 + j8.970 Ω