Qualifying Exam November 2006

Transmission Lines and Fields

Note that $\epsilon_0 = 8.8542 \cdot 10^{-12}$ F/m, and $\mu_0 = 4\pi \cdot 10^{-7}$ H/m.

A A laboratory near a radar installation has its ceiling fluorescent lights come on five times a minute, and this was then traced to the radar, with the antenna rotating at 5 rpm. The fluorescent tubes are 1 m long, and breakdown at 300 V, and the lights are on for 1 s each time. What is the polarization of the radar signal, what is its minimum average power density of the radar signal at the laboratory? The FCC regulations state that the safe 24 hour exposure level for humans at 3 GHz, assumed to be the radar frequency, is about 2 mW/cm^2. Should this laboratory install additional shielding assuming that the maximum time any employee is at the site for a maximum of 8 hours per day?

B A cake is cooked in a microwave oven operating at 2.45 GHz. The ingredients of this cake are flour, sugar and other items, 50% by weight, and have a negligible conductivity when dry with an average ϵ_r of 2.5, and water with ϵ_r of 81, with a conductivity of 2 S/m, of the remaining 50% by weight. How deep does the microwave signal penetrate into the cake dough, assuming that plane wave calculations are acceptable. Assume μ_r=1.0, the average ϵ_r, and σ are weighted mean values.

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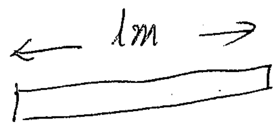
A $5\,rpm \equiv 12\,s/rev.$ $f = \frac{1}{12}\,Hz$.

Lights are on for 1s., ie field exists at the site for 1 sec every 12s ie duty cycle $= \frac{1}{12}$.

1 Fluorescent light is horizontal on the ceiling which implies <u>horizontal polarization</u>.

2 

300V breakdown.

Minimum power density $= \frac{E^2}{2\eta_0} = \frac{(300/1)^2}{2 \times 377}$

$= 119.36\,W/m^2$.

Taking account the duty cycle

min. average power density $= \frac{119.36}{12} = 9.936\,W/m^2$

$= 9.94 \times 10^{-4}\,W/cm^2$

$P_{min} = 0.994\,mW/cm^2$.

FCC regulations: $2\,mW/cm^2$ for 24 hrs.

Average employee exposure $P_{min} \times \frac{8}{24}$

$= 0.332\,mW/cm^2$

No extra sheilding required

$f = 2.45\ GHz$

$\epsilon_{rav} = 0.5 \times 2.5 + 0.5 \times 81 = 41.75$

$\sigma_{av} = 0.5 \times 0 + 0.5 \times 2 = 1\ S/m$

$\mu_r = 1 \quad , \quad \epsilon' = \epsilon_{rav} \quad , \quad \epsilon'' = \dfrac{\sigma_{av}}{\omega \epsilon_0}$

$$\epsilon_c = \left(\epsilon_0 \epsilon_r + \frac{\sigma}{j\omega}\right) = \epsilon_0\left(\epsilon_r - j\frac{\sigma}{\omega\epsilon_0}\right)$$

$$k = \omega\sqrt{\mu\epsilon_c} = \omega\sqrt{\mu_0\epsilon_0}\left(\epsilon_r - j\frac{\sigma}{\omega\epsilon_0}\right)^{1/2}$$

$$= \frac{\omega}{c}\left(41.75 - j\frac{1}{\omega \times 8.854 \times 10^{-12}}\right)^{1/2}$$

$\omega = 2\pi f = 15.394 \times 10^9\ rad/s$

$$k = \frac{15.394 \times 10^9}{3 \times 10^8}\left(41.75 - j\frac{1}{15.394 \times 10^9 \times 8.854 \times 10^{-12}}\right)^{1/2}$$

$$= 51.31(41.75 - j7.34)^{1/2}$$

$$= 51.31(6.49 - j0.566)$$

$$= 332.8 - j29.03 = \beta - j\alpha$$

$$\delta = \frac{1}{\alpha} = \frac{1}{29.03} = 3.44 \times 10^{-2}\ m$$

$$= 3.44\ cm$$