For a microstrip TL made using a gold ($\sigma = 4 \times 10^7$ S/m) land that is 3 mm wide and 20 μm thick on a 1.6 mm thick dielectric substrate ($\varepsilon_r = 2.4$, $\tan\delta = 0.004$) with a 2 oz. copper ground plane, calculate the threshold frequencies. Is an operating frequency of 5 GHz lower than these threshold frequencies?

$W = 3\,mm$, $d = 1.6\,mm$

Per (3.201), $f_{T1} = \frac{c}{2\pi d\sqrt{\frac{2}{\epsilon_r - 1}}}\tan^{-1}(\epsilon_r) = \frac{2.9979\times10^8}{2\pi(0.0016)\sqrt{\frac{2}{2.4-1}}}\tan^{-1}(2.4)$

$f_{T1} = 41.916\ GHz$

Per (3.202), $f_{T2} = \frac{c}{4d\sqrt{\epsilon_r - 1}} = \frac{2.9979\times10^8}{4(0.0016)\sqrt{2.4-1}}$

$f_{T2} = 39.589\ GHz$

Per (3.203), $f_{T3} = \frac{c}{\sqrt{\epsilon_r}(2W + d)} = \frac{2.9979\times10^8}{\sqrt{2.4}\,[2(0.003) + 0.0016]}$

$f_{T3} = 25.463\ GHz$

Per (3.204), $f_{T4} = \frac{c}{2d\sqrt{\epsilon_r}} = \frac{2.9979\times10^8}{2(0.0016)\sqrt{2.4}}$

$f_{T4} = 60.473\ GHz$

The 5 GHz operating frequency is far below all of the threshold frequencies.