ECE 5317/6351

Microwave Engineering

Fall 2019

Homework #3

Text: *Microwave Engineering* by David M. Pozar, 4th edition, Wiley, 2011.

1) Determine the dimensions of an air-filled rectangular waveguide such that $b = a/2$ and the center frequency of operation is 10 [GHz]. (The center frequency is the frequency that is halfway between the cutoff frequency of the dominant mode and the next higher-order mode.)

2) Calculate the maximum power that the waveguide in Prob. (1) can carry at 10 [GHz], assuming that the maximum allowed field level inside the guide is 3.0×10^6 [V/m] (the dielectric breakdown field strength of air).

3) The TE_{10} mode propagates in an X-band air-filled rectangular waveguide, having $a = 2.2225$ [cm] and $b = 1.0319$ [cm]. The waveguide walls are made of copper, having a conductivity of 3.0×10^7 [S/m]. Plot the total attenuation in dB/m for the waveguide versus frequency. Plot from the cutoff frequency of the TE_{10} mode up to twice the cutoff frequency of the TE_{10} mode (which is the frequency at which the next mode, the TE_{20} mode, starts to propagate). For the vertical scale, plot up to a maximum of 2 [dB/m]. (Note: The waveguide has only conductive loss because it is air filled.)

4) Assume that the rectangular X-band waveguide waveguide is Prob. (3) is now filled with Teflon ($\varepsilon_r = 2.1$), which has a loss tangent of 0.001. Calculate at 7.5 [GHz] the following for the dominant TE_{10} mode: (1) the conductor attenuation in [dB/m], (2) the dielectric attenuation in [dB/m], (3) the total attenuation in [dB/m].

5) Determine the radius of an air-filled circular waveguide such that the center frequency of operation is 10 [GHz]. (The center frequency is the frequency that is halfway between the cutoff frequency of the dominant mode and the next higher-order mode.) Compare the size of the circular waveguide with the size of the rectangular waveguide in Prob. (1), in terms of the overall diameters. (The overall diameter means the diameter of the smallest hole that the waveguide will fit through.)

6) Calculate the bandwidth (in percent) of a circular waveguide. Assume that the bandwidth is defined from the frequency region over which only the dominant mode (the TE_{11} mode for circular waveguide) propagates. (If the frequency limits are designated as f_1 and f_2, the percent bandwidth is $100(f_2 - f_1)/f_0$, where $f_0 = (f_1 + f_2)/2$.) How does the bandwidth compare

with that of the rectangular waveguide that has $b = a/2$ (assuming that both are filled with the same material)?

7) For the rectangular and circular waveguides in Probs. (1) and (5), calculate the attenuation in [dB/m] at 10 [GHz], assuming that the waveguides are both made of copper, which has a conductivity of 3.0×10^{7} [S/m].

8) An RG 59 coax is to be used to transmit a UHF signal at 500 [MHz] a distance of 30 meters. Find the total attenuation in dB over this distance. Also find the attenuation in dB due to the dielectric loss and due to the conductor loss. Use the formulas for α_c and α_d, and take the total attenuation α to be the sum of these two. Assume a = 0.292 mm, b = 1.85 mm, ε_r = 2.25. Assume for the dielectric that $\tan\delta_d = 0.001$, and for the copper conductors $\sigma = 3.0\times10^{7}$ [S/m].

9) For the RG 59 coax in the previous problem, find the maximum power that the coax can carry before dielectric breakdown occurs. Assume that the maximum allowed field level inside the coax is 2.0×10^{7} [V/m] (the dielectric breakdown field strength of the dielectric).

10) Assume that a coax is to be filled with Teflon, having ε_r = 2.1. The outer conductor has a fixed radius of 5 mm. The inner radius a is variable. The copper conductors have $\sigma = 3.0\times10^{7}$ [S/m]. Make a plot showing normalized α_c (defined as α_c in np/m divided by the square root of ω) vs. the inner radius a, for a varying from 0.1 mm to 4 mm. Use this to answer the following question: What value of Z_0 minimizes the conductor loss?

11) Assume that a coax is to be designed to have Z_0 = 50 [Ω]. The cutoff of the first higher-order waveguide mode should be at 100 [GHz]. The coax is to be filled with Teflon, having ε_r = 2.1. Determine the dimensions of the coax.