**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 3.0×106 [V/m] (the dielectric breakdown field strength of air).
3. The TE10 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 × 107 [S/m]. Plot the total attenuation in dB/m for the waveguide versus frequency. Plot from the cutoff frequency of the TE10 mode up to twice the cutoff frequency of the TE10 mode (which is the frequency at which the next mode, the TE20 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 (*εr* = 2.1), which has a loss tangent of 0.001. Calculate at 7.5 [GHz] the following for the dominant TE10 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 TE11 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 [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 *αc* and *αd*, and take the total attenuation *α* to be the sum of these two. Assume *a* = 0.292 mm, *b* = 1.85 mm, *εr* = 2.25. Assume for the dielectric that tan*δ* *d* = 0.001, and for the copper conductors *σ* = 3.0×107 [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 2.0×107 [V/m] (the dielectric breakdown field strength of the dielectric).
10. Assume that a coax is to be filled with Teflon, having *εr* = 2.1. The outer conductor has a fixed radius of 5 mm. The inner radius *a* is variable. The copper conductors have *σ* = 3.0×107 [S/m]. Make a plot showing normalized *αc* (defined as *αc* in np/mdividedby 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 *εr* = 2.1. Determine the dimensions of the coax.