ECE 3317
Fall 2023

Homework #10

Assigned: Thursday, Nov. 16
Due: Tuesday, Nov. 28

Do Probs. 1, 3–8.

1) Find the frequency ranges for a single TE_{10} mode of operation for an air-filled rectangular waveguide whose dimensions are:

   (a) 0.9 × 0.4 inches (X-band)
   (b) 0.10 × 0.05 inches (W-band)

2) Calculate the time-average power flowing in the z direction down a rectangular waveguide carrying the dominant TE_{10} mode, in terms of field E_{y0} at the center of the waveguide. Do this by integrating the Poynting vector over the cross section of the waveguide. (Note that the fields of the dominant TE_{10} mode are given in the class notes.) The answer should be:

$$P_z = \left(\frac{ab}{4\omega\mu_0} \right) \beta \left| E_{y0} \right|^2 \ [\mathrm{W}].$$

3) Design the dimensions of an air-filled waveguide to be used for transmission of electromagnetic power at 10 GHz. This frequency should be at the middle of the operating frequency band. The design should also allow maximum power transfer without sacrificing the operating frequency bandwidth. (This means that $b = a / 2$.)

   Then find the maximum time-average power in watts that the waveguide can transmit. Use a safety factor of 2 (hence, the maximum value of the electric field should not exceed $E_c/2$). The breakdown field strength E_c in air (at atmospheric pressure) is assumed to be 3×10^6 [V/m]. (See the formula for the power flow in Prob. 2.)

4) List, in ascending order, the cutoff frequencies for the first ten modes of a rectangular waveguide, normalized to the cutoff frequency of the TE_{10} mode. (That is, for each mode, you will be calculating the cutoff frequency of that mode divided by the cutoff frequency of the TE_{10} mode.) Assume that $b = a / 2$. Give numerical values for the normalized cutoff frequencies and clearly identify the mode number and type (TM or TE) for each mode. (Note that some modes may have the same cutoff frequency.)

5) Repeat the above problem assuming that $a = b$. From your results, can you explain why a square waveguide is not normally used in practice?

6) A rectangular waveguide with $a > b$ is air-filled and operates at 18 [GHz]. Assume that the dimension a is such that the cutoff frequency of the TE_{10} mode is 12 GHz. Determine the guided wavelength λ_g and the phase constant β of this mode at 18]GHz]. Find the distance required such that the fields of this mode will be reduced in magnitude by 20 dB if the operating frequency is now changed to 10 GHz (keeping the waveguide dimensions that same).

7) An important use of waveguide theory is in the design of shielded rooms. These rooms are used to isolate sensitive equipment and experiments from the effects of external electromagnetic fields, as well as to prevent the radiation from the equipment in the room from reaching the external environment. However, the room cannot be a continuous enclosure since air vents must penetrate the walls so that personnel can operate the test equipment in the room. In order to restrict electromagnetic penetration through these vents while allowing airflow, a "honeycomb" structure is inserted into the vent. This consists of a large number of small, rectangular tubes which are welded together. Each tube may be viewed as a waveguide. The intent is for these tubes to operate as a "waveguide below cutoff" in restricting penetration of external and internal fields. If the cross-section of each tube of the vent structure is square with dimensions 0.5 by 0.5 cm, determine the range of frequencies that are excluded by the structure.

8) As a continuation of the above problem, assume that the length of the vent tubes (in the direction perpendicular to the wall) is 5.0 cm. Calculate the dB of attenuation going through the vent for a wave at 1.0 GHz, basing your answer on the dominant TE_{10} mode.