ECE 451 **Homework 2** **Due Wednesday February 26, 2025**

1. A parallel-plate waveguide is filled with a dielectric $\varepsilon = 9\varepsilon_o$ and $\mu = \mu_o$. The separation between the plates is 2.5 cm. Determine the propagating modes for a wave of frequency 5 GHz. For each propagating mode, fill in the following table. Waves are incident on the plates with an angle θ with respect to the normal to the plates. v_{pz} and v_g are the phase and group velocities respectively.

Mode	f_c (GHz)	θ (deg)	v_{pz} (m/s)	v_g (m/s)
TEM				
TE_1				
TM_1				
TE_2				
TM_2				

2. An air-filled rectangular waveguide has largest side a = 1 cm. Find the length of the side b, necessary to have identical cutoff frequency for the TE_{20} and TM_{11} modes.

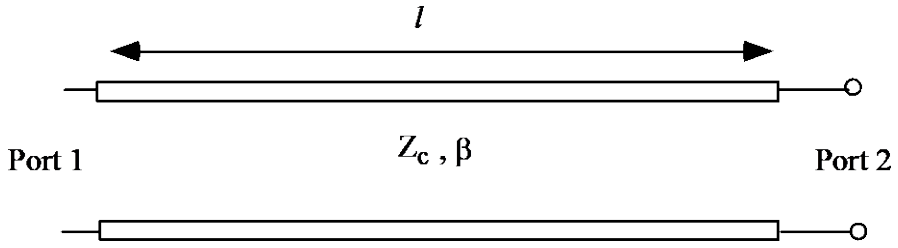
3. An air-filled, X-band (8-12GHz), WC-94 circular waveguide has an inner diameter of 2.383 cm.

(a) Determine the cutoff frequencies of the TE_{11}, TM_{01}, and TE_{21} modes.

(b) Find the modes that will propagate through this guide at 10 GHz.

(c) Find the frequency range within which only the TE_{11} mode propagates.

4. A transmission line has characteristic impedance Z_c, propagation constant β and length l. Use Z_O as the reference impedance. Define $X = e^{-j\beta l}$ and $\Gamma = \dfrac{Z_c - Z_o}{Z_c + Z_o}$.



(a) Find S_{11} in terms of X and Γ.

(b) Find S_{21} in terms of X and Γ.

5. The S parameters of a three-port are as follows (the S parameters are referred to a 50 Ω system reference impedance):

$$\begin{bmatrix} 0.2\angle 180° & 0.8\angle -45° & 0.1\angle 45° \\ 0.8\angle -45° & 0.2\angle 0° & 0.1\angle 90° \\ 0.1\angle 45° & 0.1\angle 90° & 0.1\angle 180° \end{bmatrix}$$

(a) Is the three-port reciprocal? Explain your answer.

(b) Write down the criteria for a network to be lossless.

(c) Is the three-port lossless? You must show your working.

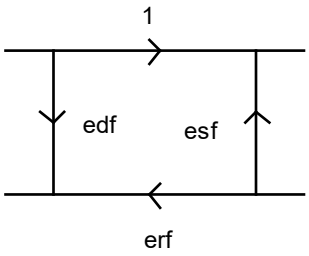
(d) Draw the SFG of the three-port.

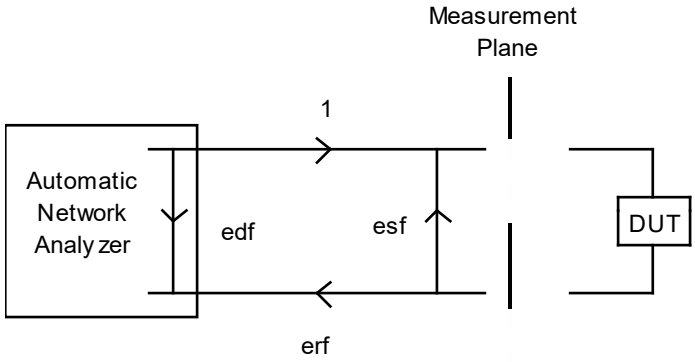
(e) A 50 Ω load is attached to Port 3. Use SFG operations to derive the SFG of the two-port with just Ports 1 and 2. Write down the two-port S parameter matrix of the simplified network.

6. Perform the one-port three-term error correction analysis (i. e. find the equations for the error terms and the relation between measured and actual S_{11}) using the following combinations of calibration standards

(a) matched termination, offset short and open

(b) matched termination, offset short and shielded open


1
edf
esf
erf


Measurement
Plane
1
Automatic
Network
Analyzer
edf
esf
DUT
erf