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**ECE 5317/6351**

**Microwave Engineering**

**Exam 2**

**Fall 2019**

Instructions

1. This exam is open book and notes. Calculators and Smith chart tools (e.g. compasses and rulers) may be used. Laptops and any devices that may be used for communication are not allowed.
2. Please show *all of your work* and *write neatly* in order to receive credit. No credit will be given if the work required to obtain the solution is not shown, or if it is not easily readable.
3. Put all of your answers in terms of the parameters given in the problems, unless otherwise noted.
4. Include units with all numerical answers in order to receive full credit.
5. Perform all of your work on the paper provided. If you need more space, you may write on the backs of the pages.

**Problem 1 (30 pts.)**

A parallel-plate waveguide consists of two perfectly conducting sheets of metal separated by a nonmagnetic dielectric slab of thickness *h* as shown below. There are four types of modes that can propagate inside this structure: TM*x*odd ,TE*x*odd , TM*x*even, TE*x*even. (Assume that there is no *y* variation of the fields for these modes.)

a) Use a TEN model to derive transcendental equations for the wavenumber *kz* for each of the four types of modes.

b) Solve the transcendental equations analytically to get exact closed-form expressions for the wavenumber *kz* for each of the four types of modes.

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**Problem 2 (35 pts.)**

Consider a four port device that consists of four microstrip lines arranged in a square shape as shown below. All lines have a characteristic impedance of *Z*0 and a guided wavelength of *λg*. The length of each side of the square is *λg*/2. The incoming lines that are connected to each corner of the square also have a characteristic impedance of *Z*0. Each corner of the square is considered to be a port, as labeled in the figure. (That is, the reference planes for the ports on the main (horizontal) feed lines are at the points where the feed lines meet the vertical lines.)

Use even/odd mode analysis to find the following *S* parameters: *S*11, *S*21, *S*31, *S*41.

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**Problem 3 (35 pts.)**

It is desired to match an incoming air-filled rectangular waveguide to one that is filled with Teflon, having , as shown below (a top view is shown below). The dimensions of the rectangular waveguide are *a* = 2.0 [cm] and *b* = 1.0 [cm]. The design is for a center frequency of 10.0 [GHz]. The match is done by inserting three dielectric-filled sections of waveguide having relative permittivities , , . The lengths of these three sections are , , .

Assume that the three dielectric-filled waveguide sections are chosen so that the corresponding TEN corresponds to a three-stage Butterworth transformer. The characteristic impedances in the TEN are chosen to be equal to the wave impedances of the corresponding waveguides.

a) Design the Butterworth transformer in the TEN by finding the characteristic impedances *Z*1 , *Z*2, and *Z*3.

b) Determine the relative permittivities , ,  in the waveguide structure.

c) Determine the lengths , ,  in the waveguide structure.



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**Bonus Problem (30 pts.)**

(a) Design an *N* = 3 “type *a*” Chebyshev band-pass filter that has a matched 50 Ω load and 0.5 dB of ripple in the passband, with a center frequency of 2.5 GHz and a bandwidth of 10%.

In your design, find the element values of all six circuit elements (inductors and capacitors) in the circuit shown below.



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