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**ECE 5317/6351**

**Microwave Engineering**

**Exam 2**

**Fall 2018**

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 nonmagnetic dielectric slab is shown below. (There is no ground plane, only free space above and below the slab.) There are four types of surface-wave modes that can propagate on the slab: TM*x*odd ,TM*x*even, TE*x*odd ,TE*x*even.

a) Use a TEN model to derive a transcendental equation for the wavenumber *kz* for the TE*x*even andTM*x*odd modes.

b) Find a formula for the cutoff frequencies of the TE*x*even modes.

**Note:** Even and odd refer to the symmetry of the fields *Ey* and *Ez* about the center of the structure (*x* = 0) in the *x* direction.

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**Problem 2 (40 pts.)**

Consider a four port device that consists of two microstrip lines with a middle connecting line in between, as shown below. The two horizontal lines have a characteristic impedance of *Z*0 and a guided wavelength of *λg*0. The vertical middle line has a characteristic impedance of *Z*0*m* and a guided wavelength of *λgm*. The four ports are labeled as shown.

This device could be used to choke off a common mode while allowing a differential mode to pass through.

Use even/odd mode analysis to find the [*S*] matrix of this device. Assume that the characteristic impedance of all lines coming into the device are *Z*0.

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**Problem 3 (30 pts.)**

It is desired to match an incoming *Z*0 = 50 [Ω] microstrip line to a *ZL* = 200 [Ω] microstrip line using a two-stage Butterworth transformer as shown below.

a) Design the transformer by finding the characteristic impedances *Z*1 and *Z*2. Do not use the table in the Pozar book -- do the design by hand.

b) Determine the bandwidth of the transformer in percent. The bandwidth is defined by the frequency range over which the SWR on the incoming *Z*0 line is less than 2.0.

c) Determine the (complex) input reflection coefficient at a frequency that is 10% higher than the design frequency.

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**Bonus Problem (30 pts.)**

(a) Design an *N* = 3 “type *a*” Chebyshev low-pass filter that has a matched 50 Ω load and 0.5 dB of ripple in the passband, with a cutoff frequency of 3.0 GHz. In your design, find the element values of all three elements in the circuit shown below.

(b) Design a microstrip layout of the filter as shown below, with *Z*0 = 50 Ω and choosing *Zhigh* = 200 Ω. That is, determine *Z*1 and *βl* (where *β* is the phase constant on the high-impedance line) in the layout.

Note that the capacitors in the above circuit model are being realized by open-circuited *Z*1 stubs using Richard’s transformation, while the series inductor is being realized approximately by a short high-impedance section of line.

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