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**ECE 5317/6351**

**Microwave Engineering**

**Exam 2**

**Fall 2015**

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.

**You will have a total of 170 minutes.**

**Problem 1 (20 pts.)**

A microstrip line of characteristic impedance *Z*0 = 50 [Ω] is to be connected to a load of impedance 25+*j*(25) [Ω], using a matching circuit as shown below. (The load is connected between the end of the line and the ground plane at the connection point shown with a black dot.) The open-circuited stub line has the same characteristic impedance *Z*0 as the main line. A quarter-wave matching transformer of length *d* is also used as shown.

a) Determine the distance *d* and the stub length *l* in terms of the guided wavelengths *λgT* and *λgs* on the transformer and stub lines, respectively. Also, determine the characteristic impedance *Z*0T of the transformer line. Note: choose the smallest value of *l* possible.

b) Assume that the substrate has a relative permittivity of 2.2 and a thickness of 60 mils (one mil equals 0.001 inches or 0.00254 cm), and the frequency of operation is 10 [GHz]. Use CAD formulas to determine the width *w* and length *l* in cm. Note: Use the simple CAD formulas that neglect frequency effects, conductor loss, and conductor thickness.

Stub



Load

Substrate



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**Problem 2 (20 pts.)**

A microstrip power divider that is used to feed a circularly-polarized antenna (the antenna is not shown) is shown below. Note that the two narrow lines that connect to the input line (line 1) are each 1/4 of a guided wavelength long and have a characteristic impedance of  while all of the other lines have a characteristic impedance . The line of impedance  that connects from the T junction to port 3 is longer than the line that connects from the T junction to port 2 by one one-fourth of a guided wavelength. In particular, the line that connects from the T junction to port 2 is one guided wavelength, while the line that connects from the T junction to port 3 is 5/4 of a guided wavelength in total length (including the bend in the line). Note that port 1 is on the input line, just to the left of the T junction.

Determine *S*11, *S*22, and *S*33 for this three-port system.



Port 1

Port 2

Substrate



Port 3

Delay line



Line 1

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**Problem 3 (20 pts.)**

A microstrip line of characteristic impedance Z0 is connected to a circular microstrip ring, which then connects to another microstrip line as shown below, forming a two-port system. (This can be used to detour a microstrip line around a device in a symmetrical way.) The circular ring line has a characteristic impedance of 2*Z*0.

a) Use even/odd mode analysis to determine the *S* matrix for this two-port system with respect to the *Z*0 lines, assuming that the circumference of the ring is two guided wavelengths.

b) Repeat assuming that the circumference of the ring is one guided wavelength.



Port 1

Port 2

Substrate

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**Problem 4 (20 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.

Use a TEN model to derive a transcendental equation for the wavenumber *kz* for the TM*x*odd andTE*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 5 (20 pts.)**

It is desired to match an incoming 50 [Ω] microstrip line to a 125 [Ω] microstrip line using a three-stage Chebyshev transformer as shown below. It is desired to have a bandwidth of 50%.

a) Determine what the smallest value of the maximum reflection coefficient magnitude Γ*m* is, such that the bandwidth will be 50%.

b) Design the transformer by finding *Z*01, *Z*02, and *Z*03.



Substrate



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**Room for work**