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**ECE 6351/5317**

**Microwave Engineering**

**Exam 2**

**Fall, 2011**

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. If you need a Smith chart, please ask the instructor.
3. Please show *all of your work* and *write neatly* in order to receive credit.
4. Put all of your answers in terms of the parameters given in the problems, unless otherwise noted.
5. Include units with all numerical answers in order to receive full credit.
6. For all solutions, ***no credit*** will be given if the work required to obtain the solution is not shown.
7. Perform all your work on the paper and charts 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 power divider that is used to feed a circularly-polarized antenna (the antenna is not shown) is shown below. Note that the two 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 1/4 of a guided wavelength, while the line that connects from the T junction to port 3 is 1/2 of a guided wavelength in total length (including the bend in the line).

Determine *S*11, *S*22, *S*33, *S*21, *S*31, and *S*32 for this three-port system. Note that port 1 is on the input line, just to the left of the T junction.



Port 1

Port 2

Substrate



Port 3

Delay line



Line 1

**Room for work**

**Room for work**

**Problem 2 (20 pts.)**

A microstrip line of characteristic impedance *Z*0 = 50 [Ω] is to be connected to a load of impedance 100+*j*(100) [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) Use the Smith chart (given below) to determine the distance *d* and the stub length *l* in terms of the guided wavelength *λg* on the microstrip lines.

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* of the lines, and the distances *d* and *l* in cm.

Stub



Load

Substrate



**Room for work**



**Problem 3 (20 pts.)**

A microstrip line is connected to a microstrip ring, which then connects to another microstrip line as shown below, forming a two-port system.

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

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



Port 1

Port 2

Substrate

**Room for work**

**Room for work**

**Problem 4 (20 pts.)**

A waveguide resonator consists of a rectangular waveguide that is partially filled with a dielectric material at the ends, as shown below. The waveguides are short-circuited at the left and right ends (*z* = 0 and *z* = *L*+2*d*).

Derive a transcendental equation for the resonance frequencies of the even and odd modes inside the resonator, assuming that the modes of interest are of the form TE10p. That is, the resonant modes are based on the dominant TE10 mode of the waveguides. Even and odd refer to the symmetry of the field *Ey* about the center of the structure in the *z* direction.

*εr*

*a*

*b*

*d*

*d*

*ε*0

*L*

*εr*

*y*

*z*

**Room for work**

**Room for work**

**Problem 5 (20 pts.)**

a) Design a two-stage Butterworth transformer to connect a 50 [Ω] microstrip line to a 250 [Ω] microstrip line. Determine the characteristic impedances of the two transformer sections using small reflection theory -- do not use a table.

b) Determine the bandwidth of the impedance match (according to small-reflection theory), assuming a maximum magnitude of the reflection coefficient that corresponds to a magnitude of *S*11 on the 50 [Ω] microstrip line that is -20 dB.

c) Now assume that the operating frequency is 10% higher than the design frequency. That is, *f* = 1.1 *f*0. What is the (complex) input reflection coefficient, according to small-reflection theory?

Substrate

**Room for work**

**Room for work**