UNIVERSITI SAINS MALAYSIA

Semester I Examination
Academic Session 2005/2006

November 2005

EEE 532 – MICROWAVE CIRCUIT DESIGN

Time : 2 hours

INSTRUCTION TO CANDIDATE:

Please ensure that this examination paper contains **SIX** **(6)** printed pages including Appendices (8 pages) and **SIX** **(6)** questions before answering.

This question paper has two sections, **Section A** and **Section B**.

Answer **TWO** **(2)** question in **Section A** and **TWO** **(2)** question in **Section B.**

Answer **FOUR** **(4)** question.

Use two answer booklets which is provided where the answer for questions in **Section A** are in one answer booklets and for **Section B** in another answer booklet.

Distribution of marks for each question is given accordingly.

All questions must be answered in English.

...2/-

Section A: Answer <u>TWO</u> (2) question

A1. (a) Design a matching section using L-network to match a load of Z_L= 60 – j30 ohm to a 50 ohm line using lumped components at frequency of 1 GHz. Give all the possible solutions.

(10 marks)

(b) Design a three section binomial transformer to match a 150 ohm load to a 50 ohm line.

(15 marks)

A2. Design a 10dB broadband 3 sections maximally flat coupled line coupler using a substrate of ε_r=10 and thickness of 1 mm with center frequency of 3 GHz. The input of all ports are to be 50 ohm . Calculate all the parameters of the microstrip using the graph in Appendix I. Given that the voltage at port 3 in terms of port 1 is:

$$V_3 = 2jV_1 \sin\theta \, e^{-jN\theta}\left[C_1 \cos(N-1)\theta + C_2 \cos(N-3)\theta + \ldots \tfrac{1}{2}C_M\right]$$

where N=number of section , M=(N+1)/2 , $C_o = \left|\frac{V_3}{V_1}\right|_{\theta=\pi/2}$

Assume that the coupler is symmetrical such that C_1 = C_N, C_2= C_{N-1} etc.

(25 marks)

...3/-

A3. The GaAs FET has the following S-parameters at 4 GHz (referred to 50 ohm line) as follows

S_{11}		S_{21}		S_{12}		S_{22}	
Mag	Ang (degree)	Mag	Ang	Mag	Ang	Mag	Ang
0.72	-116	2.60	76	0.03	51	0.73	-54

(a) Check the stability of the transistor. (5 marks)

(b) Determine the unilateral figure of merit. (5 marks)

(c) Design an amplifier for maximum gain at 4 GHz using stub matching section. Leave the answer in wavelength.

(15 marks)

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Section B : Answer TWO (2) question

B4. A microwave receiver operating at a frequency range of 3 GHz to 5 GHz. The system must reject the signal outside the operating range to avoid interferences from unwanted transmission. Design a 3-pole coupled-line microstrip filter for the system having a specification as the following:

Microwave Laminate: Duroid 5880
Substrate Thickness: 0.7878 mm
Copper Thickness: 35 um
Dielectric Constant: 2.5
Equal-Ripple LPF Prototype: 0.5 dB

(25 Marks)

B5. (a) Referring to Figure 2, explain the operation of the negative resistance oscillator mathematically.

(10 Marks)

(b) The phase noise is the Figure of Merit of an oscillator, explain what is the phase noise in the oscillator.

(5 Marks)

(c) Explain what is the dielectric resonator. (5 Marks)

(d) Briefly describe the feedback type oscillator topology and explain what are the important criterions in the design of a feedback oscillator.

(5 Marks)

...5/-

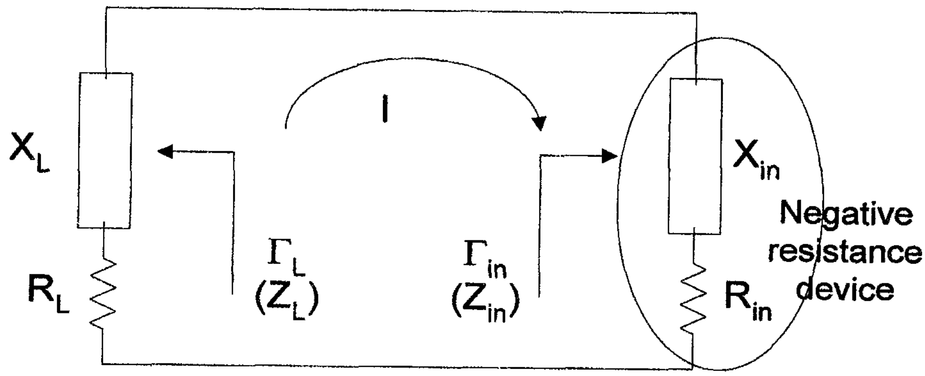

Figure 2

B6. (a) The down-converter installed on the parabolic antenna having the following frequency parameters. Determine the receiving frequency.

$$V_{LO}(t) = \cos 2\pi 11 \times 10^9 t \qquad V_{IF}(t) = \cos 2\pi 1 \times 10^9 t$$

(5 Marks)

(b) Design a single balanced diode mixer using a microstrip coupler operating at 5 GHz. The microwave laminate is FR4 having the thickness of 1.5 mm and the dielectric constant of 2.5.

(15 Marks)

(c) A mixer for a superheterodyne receiver has an RF input power of -20 dBm. An output power on the intermediate frequency (IF) port is -40 dBm. Determine the conversion loss of the mixer.

(5 Marks)

...6/-

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	0.6986	1.000									
2	1.4029	0.7071	1.9841								
3	1.5963	1.0967	1.5963	1.000							
4	1.6703	1.1926	2.3661	0.8419	1.9841						
5	1.7058	1.2296	2.5408	1.2296	1.7058	1.000					
6	1.7254	1.2479	2.6064	1.3137	2.4758	0.8696	1.9841				
7	1.7372	1.2583	2.6381	1.3444	2.6381	1.2583	1.7372	1.000			
8	1.7451	1.2647	2.6564	1.3590	2.6964	1.3389	2.5093	0.8796	1.9841		
9	1.7504	1.2690	2.6678	1.3673	2.7239	1.3673	2.6679	1.2690	1.000		
10	1.7543	1.2721	2.6754	1.3725	2.7392	1.3806	2.7231	1.3485	2.5239	0.8842	1.9841

Table 2 : Element values for Equal-Ripple Low-Pass Filter Prototypes 0.5 dB ripple.

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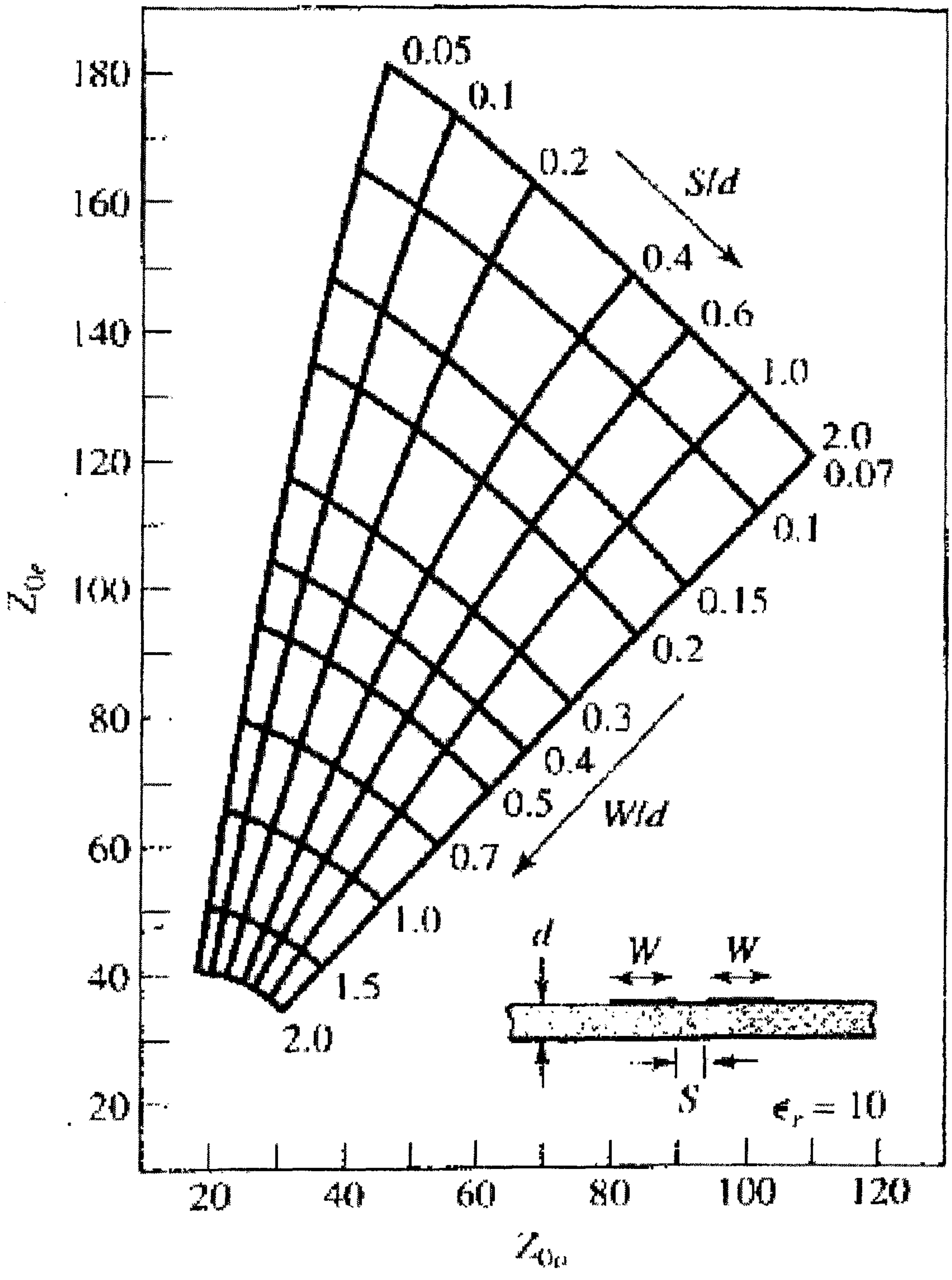
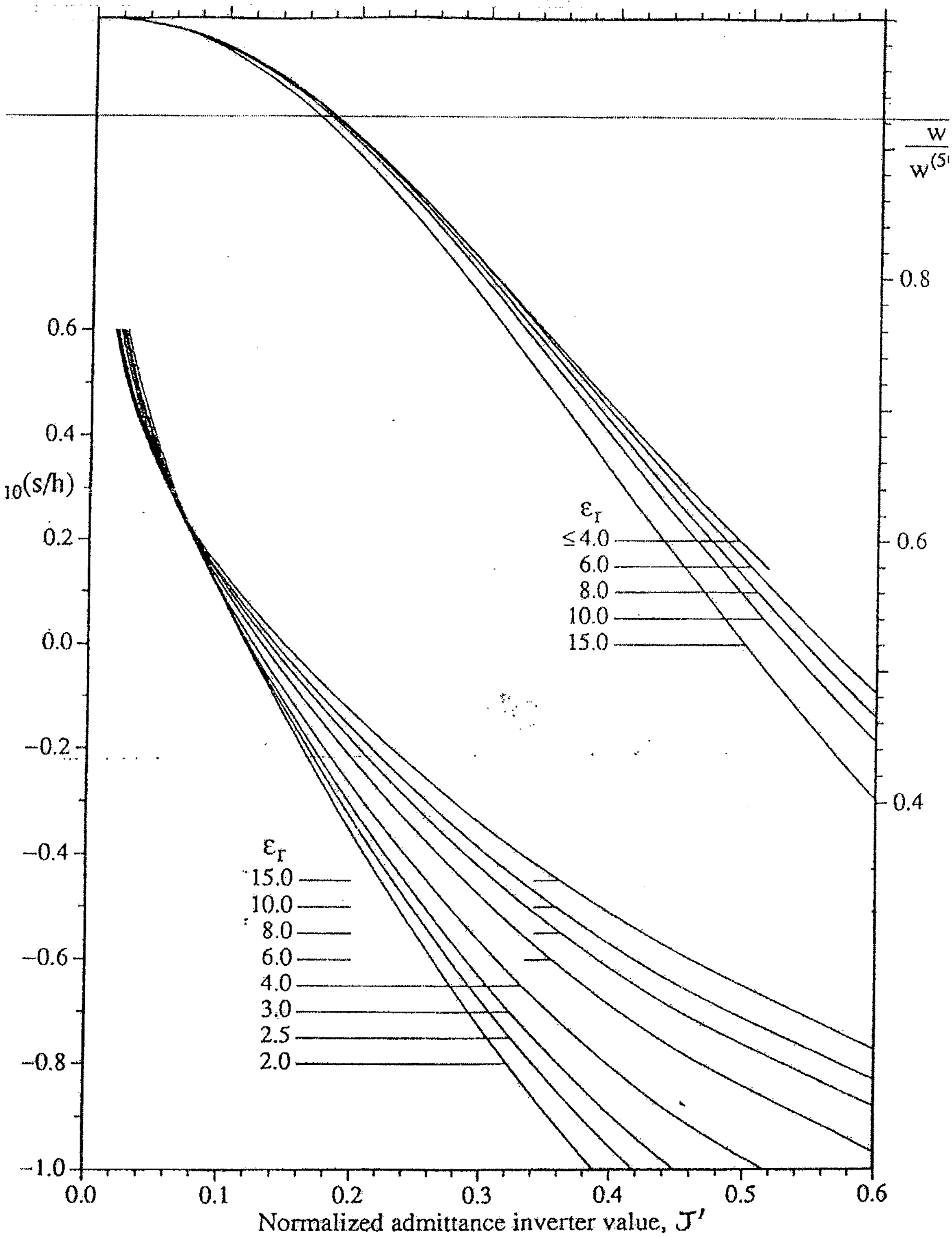

0.05
0.1
0.2
S/d
0.4
0.6
1.0
2.0
0.07
0.1
0.15
0.2
0.3
0.4
0.5
W/d
0.7
1.0
1.5
2.0
d
W
W
S
$\epsilon_r = 10$
180
160
140
120
100
80
60
40
20
Z_{0e}
20
40
60
80
100
120
Z_{0o}


0.6
0.4
10(s/h)
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Normalized admittance inverter value, J′
w
w(5
0.8
0.6
0.4
εr
≤4.0
6.0
8.0
10.0
15.0
εr
15.0
10.0
8.0
6.0
4.0
3.0
2.5
2.0

2

APPENDIX **[EEE 532]**

Important Formulas:

Network parameters

S=parameter

$$S_{11} = \left.\frac{V_{r1}}{V_{i1}}\right|_{V_{r2}=0} \qquad S_{12} = \left.\frac{V_{t2}}{V_{i2}}\right|_{V_{r2}=0} \qquad S_{21} = \left.\frac{V_{t1}}{V_{i1}}\right|_{V_{r1}=0} \qquad S_{22} = \left.\frac{V_{rt2}}{V_{i2}}\right|_{V_{r1}=0}$$

ABCD parameter

$$A = \left.\frac{V_1}{V_2}\right|_{I_2=0} \qquad B = \left.\frac{V_1}{-I_2}\right|_{V_2=0} \qquad C = \left.\frac{I_1}{V_2}\right|_{I_2=0} \qquad D = \left.\frac{I_1}{-I_2}\right|_{V_2=0}$$

Conversion

$$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \frac{1}{Z_oA + B + Z_o^2C + Z_oD}\begin{bmatrix} Z_oA + B - Z_o^2C - Z_oD & 2Z_o(AD - BC) \\ 2Z_o & -Z_oA + B - Z_o^2C + Z_oD \end{bmatrix}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \frac{1}{2S_{21}}\begin{bmatrix} (1+S_{11})(1-S_{22}) + S_{12}S_{21} & Z_o((1+S_{11})(1+S_{22}) - S_{12}S_{21}) \\ \frac{1}{Z_o}((1-S_{11})(1-S_{22}) - S_{12}S_{21}) & (1-S_{11})(1+S_{22}) + S_{12}S_{21} \end{bmatrix}$$

Butterworth lowpass filter

$g_k = 2\sin(2k-1)\frac{\pi}{2n}$ where k=1,.........., n

$g_0 = g_{n+1} = 1$

$$n = \frac{\log_{10}\left(10^{A/10} - 1\right)}{2\log_{10}(\omega/\omega_c)}$$

$$C_k = \frac{g_k}{Z_o\omega_c}$$

$$L_k = \frac{Z_o g_k}{\omega_c}$$

APPENDIX

Available Power gain:

$$G_A = \left(\frac{|S_{21}|^2 (1-|\Gamma_S|^2)}{|1-S_{11}\Gamma_S|^2 (1-|\Gamma_{out}|^2)} \right)$$

Transducer Power Gain:

$$G_T = \frac{|S_{21}|^2 (1-|\Gamma_S|^2)(1-|\Gamma_L|^2}{|1-\Gamma_S\Gamma_{in}|^2 |1-S_{22}\Gamma_L|^2}$$

Bilateral

$$\Delta = S_{11}S_{22} - S_{12}S_{21}$$

$$K = \frac{1-|S_{11}|^2 - |S_{22}|^2 + |\Delta|}{2|S_{12}S_{21}|}$$

$$\Gamma_s = \frac{B_1 \pm \sqrt{B_1^2 - 4|C_1|^2}}{2C_1} \qquad B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 \qquad C_1 = S_{11} - \Delta S_{22}^*$$

$$\Gamma_L = \frac{B_2 \pm \sqrt{B_2^2 - 4|C_2|^2}}{2C_2} \qquad B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta|^2 \qquad C_2 = S_{22} - \Delta S_{11}^*$$

$$\Gamma_{in} = \Gamma_S^* = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L} \qquad \Gamma_{out} = \Gamma_L^* = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1-S_{11}\Gamma_S}$$

$$C_L = \frac{(S_{22} - \Delta S_{11}^*)^*}{|S_{22}|^2 - |\Delta|^2} \qquad R_L = \left| \frac{S_{12}S_{21}}{|S_{22}|^2 - |\Delta|^2} \right|$$

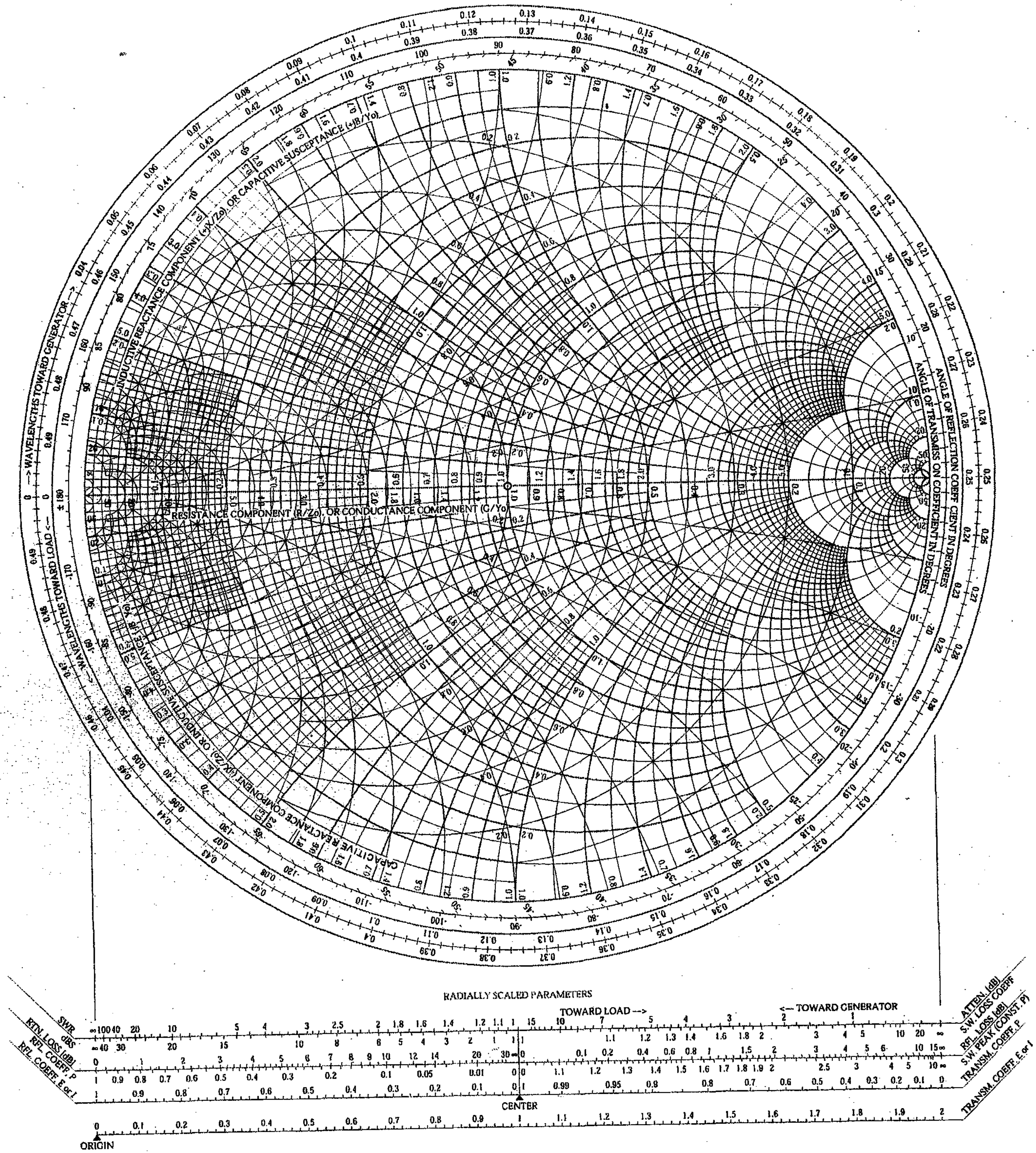
$$C_S = \frac{(S_{11} - \Delta S_{22}^*)^*}{|S_{11}|^2 - |\Delta|^2} \qquad R_S = \left| \frac{S_{12}S_{21}}{|S_{11}|^2 - |\Delta|^2} \right|$$

$$G_{T\max} = \frac{1}{1-|\Gamma_s|^2} |S_{21}|^2 \frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$$

APPENDIX

NAME	TITLE	DWG. NO.
		DATE
SMITH CHART FORM ZY-01-N	Microwave Circuit Design - EE523 - Fall 2000	

NORMALIZED IMPEDANCE AND ADMITTANCE COORDINATES



NAME	TITLE	DWG. NO.
SMITH CHART FORM 82-BSPR (9-66)	KAY ELECTRIC COMPANY, PINE BROOK, N.J. © 1966. PRINTED IN U.S.A.	DATE

IMPEDANCE OR ADMITTANCE COORDINATES

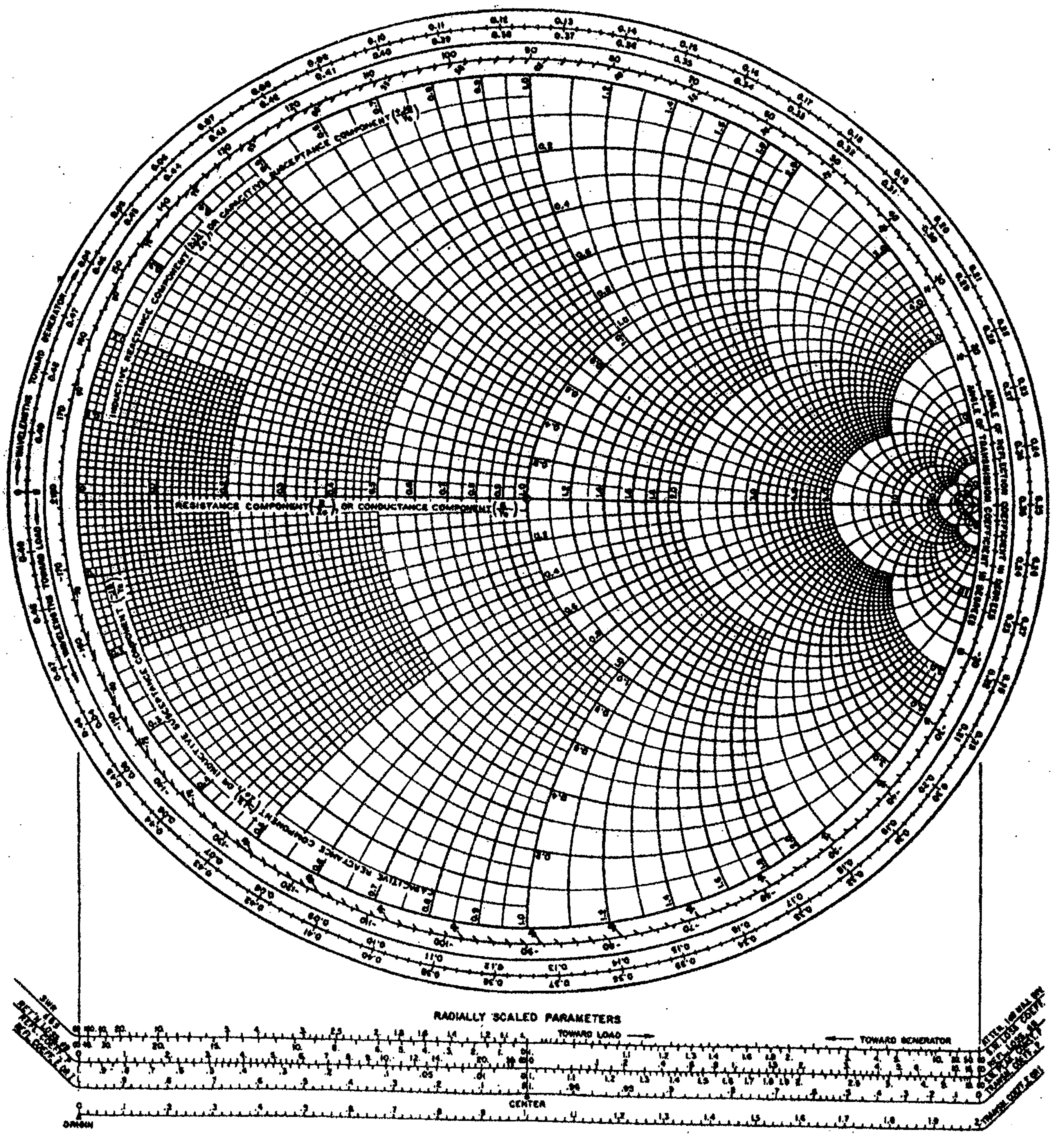


Figure 4.8 Smith chart, reprinted by permission of P. H. Smith, renewal copyright, 1976.