INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date........ FN/AN Time: **3** Hrs., Full Marks. 50, Deptt: **E & ECE**

No. of Students **97.** End Autumn Semester Exam. **Nov.: 2011**

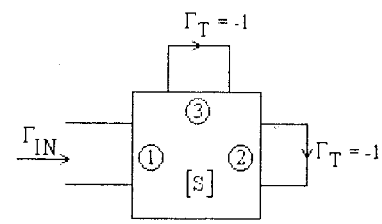
Subject No.: **EC31005** Subject: **RF & Microwave Engineering**

3rd **Yr.** B.Tech(H)/M.Tech(Dual) **INSTRUCTIONS:** Answer ALL Questions

All symbols and variables have their usual meaning.

Note 1: The numbers in square brackets at the right-hand side of the text indicate the provisional allocation of maximum marks per question or sub-section of a question.

Q.1 Calculate the input reflection coefficient (at port 1) of a three port network where ports 2 and 3 are terminated by short circuits.



[10]

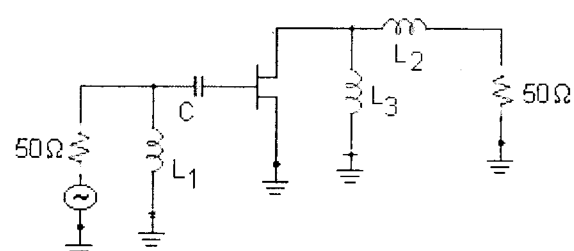
Q.2 Design an amplifier for maximum gain at 5.0 GHz with a GaAs FET that has the following S parameters (Z_0=50Ω) : $[S]=\begin{bmatrix} 0.65\angle-140^\circ & 0.04\angle60^\circ \\ 2.4\angle50^\circ & 0.70\angle-65^\circ \end{bmatrix}$.

Design matching sections using open-circuited shunt stubs. **[10]**

Q.3 Design an amplifier with maximum G_{TU} using a transistor with the following S parameters (Z_0=50Ω) at 6.0 GHz :

$$[S]=\begin{bmatrix} 0.61\angle-170^\circ & 0.0 \\ 2.24\angle32^\circ & 0.72\angle-83^\circ \end{bmatrix}.$$

Design L-section matching sections using lumped elements as shown in the fig.



[10]

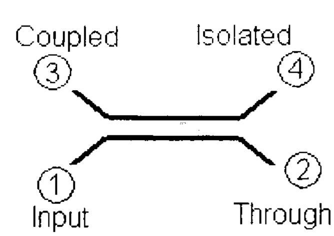
Q.4 A GaAs FET has the following scattering and noise parameters at 6.0 GHz (Z_0=50Ω) :

$[S]=\begin{bmatrix} 0.6\angle-60^\circ & 0.0 \\ 2.0\angle81^\circ & 0.7\angle-60^\circ \end{bmatrix}$ and .

F_{MIN}=2.0 dB, $\Gamma_{opt} = 0.62\angle100^\circ$, and R_N=20 Ω. Design an amplifier to have a gain of 6 dB, and the minimum noise figure possible with this gain. Design matching sections using open-circuited shunt stubs. **[10]**

Q.5 A directional coupler has the scattering matrix given below. Find the directivity, coupling, insertion loss, and the return loss at the input port when the other ports are terminated in matched loads.

$$[S]=\begin{bmatrix} 0.032\angle30^\circ & 0.96\angle0^\circ & 0.1\angle90^\circ & 0.0018\angle90^\circ \\ 0.96\angle0^\circ & 0.032\angle30^\circ & 0.0018\angle90^\circ & 0.1\angle90^\circ \\ 0.1\angle90^\circ & 0.0018\angle90^\circ & 0.034\angle30^\circ & 0.018\angle0^\circ \\ 0.0018\angle90^\circ & 0.1\angle90^\circ & 0.018\angle0^\circ & 0.033\angle30^\circ \end{bmatrix}$$



[10]

P.T.O.

Contd.

Note 2:

You may need:

$$T = \frac{P_1(1-\Sigma L_1^1 + \Sigma L_2^1 + ..) + P_2(1-\Sigma L_1^2 + \Sigma L_2^2 + ..) + ..}{1-\Sigma L_1 + \Sigma L_2 + ..}$$

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

$$B_1 = 1+|S_{11}|^2 - |S_{22}|^2 - |\Delta|^2; \; B_2 = 1-|S_{11}|^2 + |S_{22}|^2 - |\Delta|^2; \; C_1 = S_{11} - \Delta S_{22}^*; \; C_2 = S_{22} - \Delta S_{11}^*;$$

$$\Gamma_{ML} = \frac{B_2 - \sqrt{B_2^2 - 4|C_2|^2}}{2C_2}; \qquad \Gamma_{MS} = \frac{B_1 - \sqrt{B_1^2 - 4|C_1|^2}}{2C_1}; \qquad G_{TM} = \frac{|S_{21}|}{|S_{12}|}(K - \sqrt{K^2-1});$$

$$G_T = \frac{1-|\Gamma_S|^2}{|1-\Gamma_{IN}\Gamma_S|^2}|S_{21}|^2 \frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}; \qquad G_{TU} = \frac{1-|\Gamma_S|^2}{|1-S_{11}\Gamma_S|^2}|S_{21}|^2 \frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2} = G_{1U}.G_0G_{2U}$$

$$U = \frac{|S_{11}S_{22}S_{12}S_{21}|}{(1-|S_{11}|^2)(1-|S_{22}|^2)}; \qquad \frac{1}{(1+U)^2} < \frac{G_T}{G_{TU}} < \frac{1}{(1-U)^2}$$

$$g_i = \frac{G_{iU}}{G_{i\max}} = G_{iU}(1-|S_{ii}|^2); \qquad d_i = \frac{g_i|S_{ii}|}{1-|S_{ii}|^2(1-g_i)}; \quad R_i = \frac{\sqrt{1-g_i}\,(1-|S_{ii}|^2)}{1-|S_{ii}|^2(1-g_i)};$$

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

$$G_P = |S_{21}|^2 g_P; \quad g_P = \frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2 - |S_{11} - \Delta\Gamma_L|^2};$$

$$g_P = \frac{1-|\Gamma_L|^2}{1-|S_{11}|^2 + |\Gamma_L|^2(|S_{22}|^2 - |\Delta|^2) - 2\,\mathrm{Re}(\Gamma_L C_2)};$$

$$G_A = |S_{21}|^2 g_A; \quad g_A = \frac{1-|\Gamma_S|^2}{|1-S_{11}\Gamma_S|^2 - |S_{22} - \Delta\Gamma_S|^2};$$

$$g_A = \frac{1-|\Gamma_S|^2}{1-|S_{22}|^2 + |\Gamma_S|^2(|S_{11}|^2 - |\Delta|^2) - 2\,\mathrm{Re}(\Gamma_S C_1)};$$

$$R_p = \frac{\left[1-2K|S_{12}S_{21}|g_p + |S_{12}S_{21}|^2 g_p^2\right]^{1/2}}{|1+g_p(|S_{22}|^2 - |\Delta|^2)|}; \qquad C_p = \frac{g_p C_2^*}{1+g_p\left(|S_{22}|^2 - |\Delta|^2\right)};$$

$$F = F_1 + \frac{F_2 - 1}{G_1}; \quad F = F_{MIN} + \frac{R_N}{G_S}|Y_S - Y_{OPT}|^2; \quad Y_S = \frac{1}{Z_0}\frac{1-\Gamma_s}{1+\Gamma_s}; \quad Y_{OPT} = \frac{1}{Z_0}\frac{1-\Gamma_{OPT}}{1+\Gamma_{OPT}};$$

$$C_F = \frac{\Gamma_{OPT}}{N+1}; \quad R_F = \frac{\sqrt{N(N+1-|\Gamma_{OPT}|^2)}}{N+1}; \quad \text{where} \quad N = \frac{|\Gamma_S - \Gamma_{OPT}|^2}{1-|\Gamma_S|^2} = \frac{F - F_{MIN}}{4R_N/Z_0}|1+\Gamma_{OPT}|^2$$

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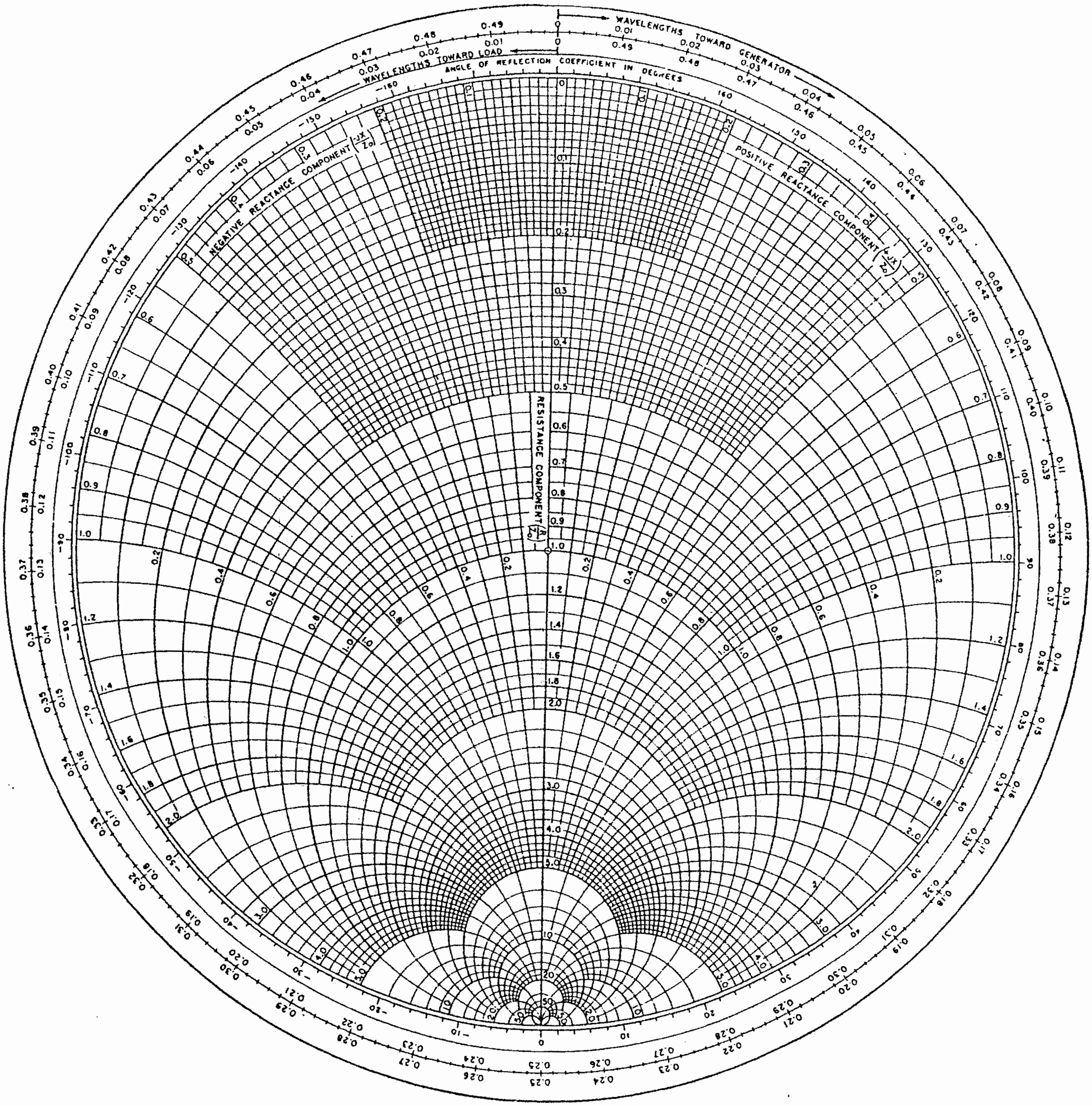

WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
NEGATIVE REACTANCE COMPONENT (-jX/Zo)
POSITIVE REACTANCE COMPONENT (+jX/Zo)
RESISTANCE COMPONENT (R/Zo)

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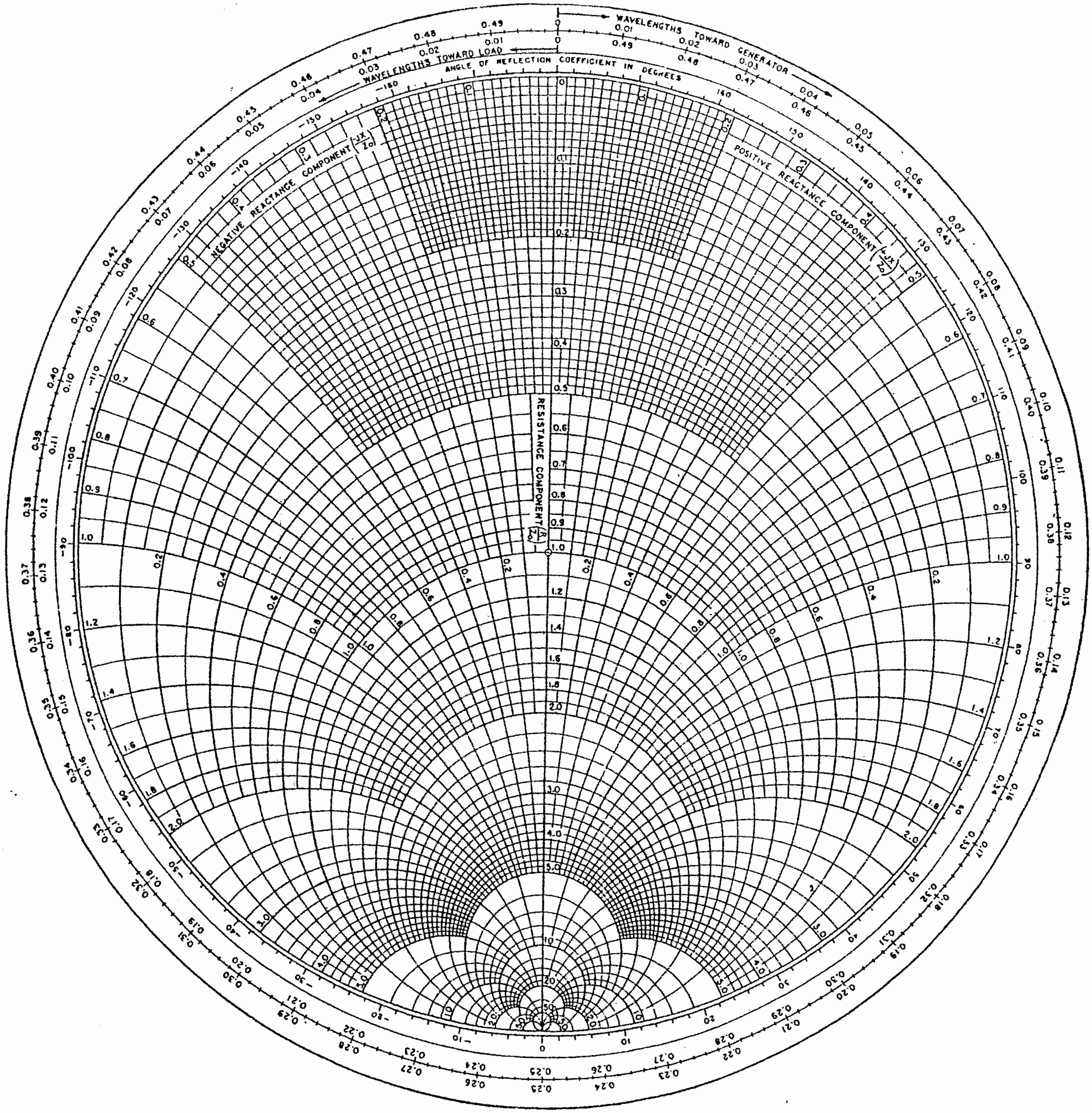

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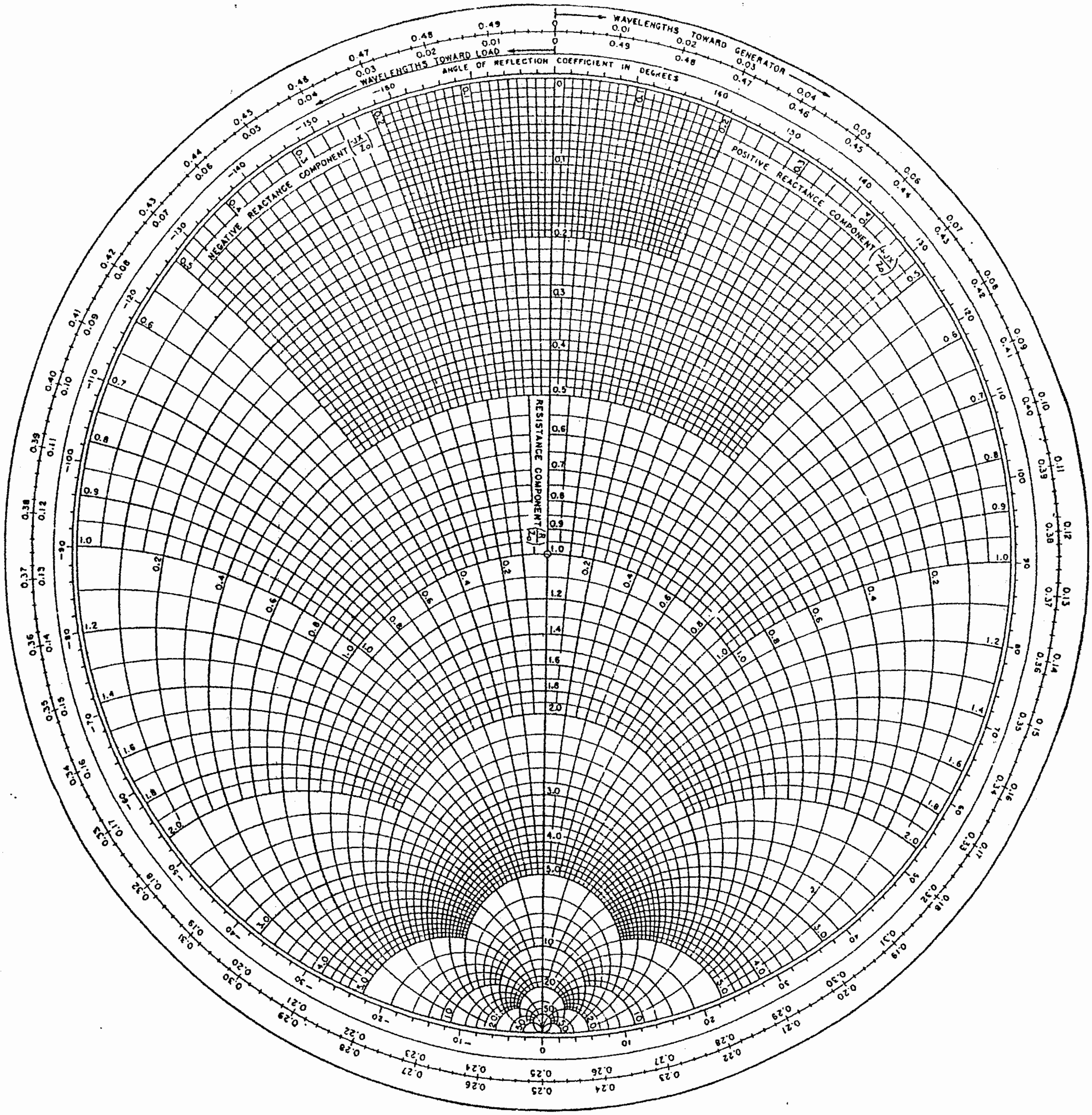
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