FERMILAB
ENGINEERING NOTE

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SUBJECT: Impedance Matching Lab.

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Purpose

Design, build, and test a single stub tuner matching network for matching various resistive impedances to 50 Ω at 60 MHz.

Equipment

Network Analyzer

Various mystery impedances in pumona boxes.

Assorted lengths of RG-58 cable with BNC connectors

BNC tees, bullets, and barrels

Smith Charts

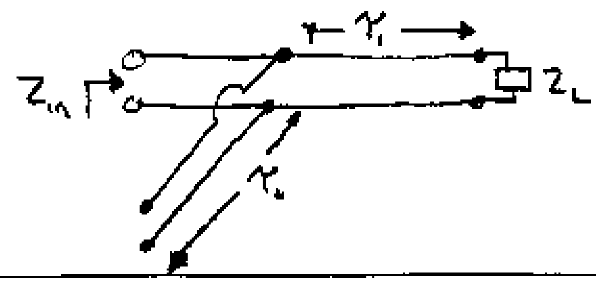
Compass & ruler

Calculator

Background Info.

A single stub tuner has the following topology.

See class notes for an example on how to design a single stub tuner.



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For a given "mystery" load:

1) Set the network analyzer (NWA) to measure S_{11} at a center freq. of 60 MHz with a span of 0 Hz.
2) The cables out of NWA should be equipped with BNC adapters.
3) Calibrate the S_{11} measurement with an OPEN response.
4) Set the display format to Smith Chart and verify that the calibration is valid by measuring an "open" and a 50Ω load.
5) Attach a "mystery" load to port ① and measure the complex impedance and reflection coefficient.
6) On a Smith Chart (on paper) determine the angle needed to rotate the reflection coefficient to the "mirror" real circle. There are 2 answers. See Smith Chart ①

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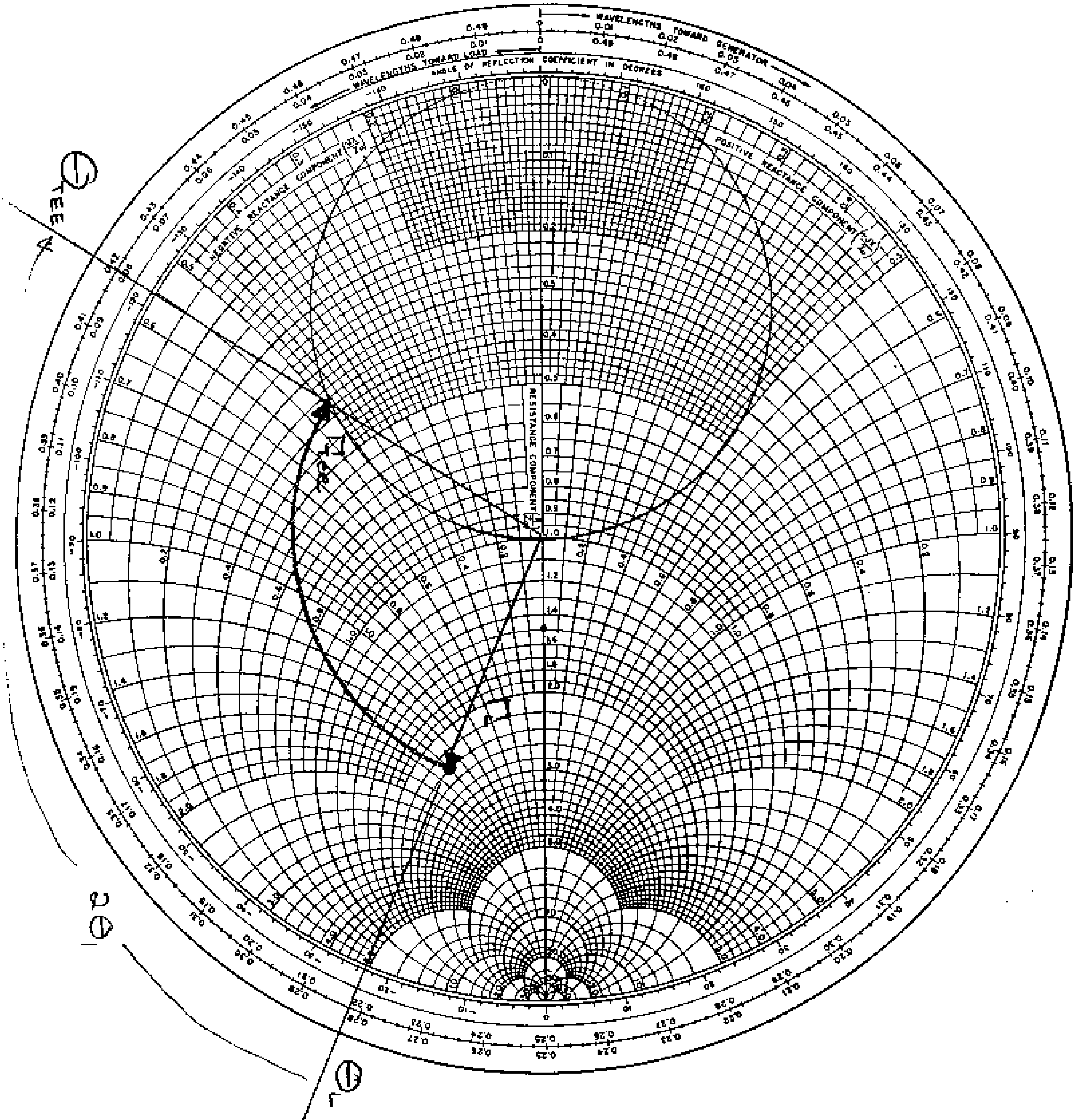
Smith Chart (1)



Ref: Phillip H. Smith "Transmission Line Calculator" Electronics Jan. 1939 and Jan. 1944

7) Calculate τ_1

$$2\Theta_1 = 360° \cdot f \cdot 2\tau_1 \quad f = 60 \text{ MHz.}$$

8) Add a length of cable that is $\leq \tau_1$ to the mystery load.

9) Switch the NWA display to phase format and measure the phase of the Γ of the delayed mystery load. Add BNC Bullets and Barrels onto the load delay cable until the phase of the reflection coefficient = the phase of Γ_{TEE}

10) Measure the complex impedance and Γ of the delayed load. Does it equal Z_{TEE} & Γ_{TEE}?

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11). On Smith Chart, flip rotated impedance to the admittence chart and determine what value of imaginary admittance must be added to bring Γ to zero. (Smith Chart 2)

12) On Smith Chart, determine what angle is needed to rotate the impedance of an open circuit to the value calculated in step (11). From the angle ($2\theta_2$), calculate the length of cable needed to give a phase shift @ 60 MHz of θ_2 (τ_2) (Smith Chart 3)

13) Remove the delayed mystery load from the NWA. Add an open circuited cable with a length $\leq \tau_2$ onto port (1) of the NWA. With the NWA in phase format, add BNC bullets and barrels to this cable until the phase of the reflection coefficient $= 2\theta_2$.

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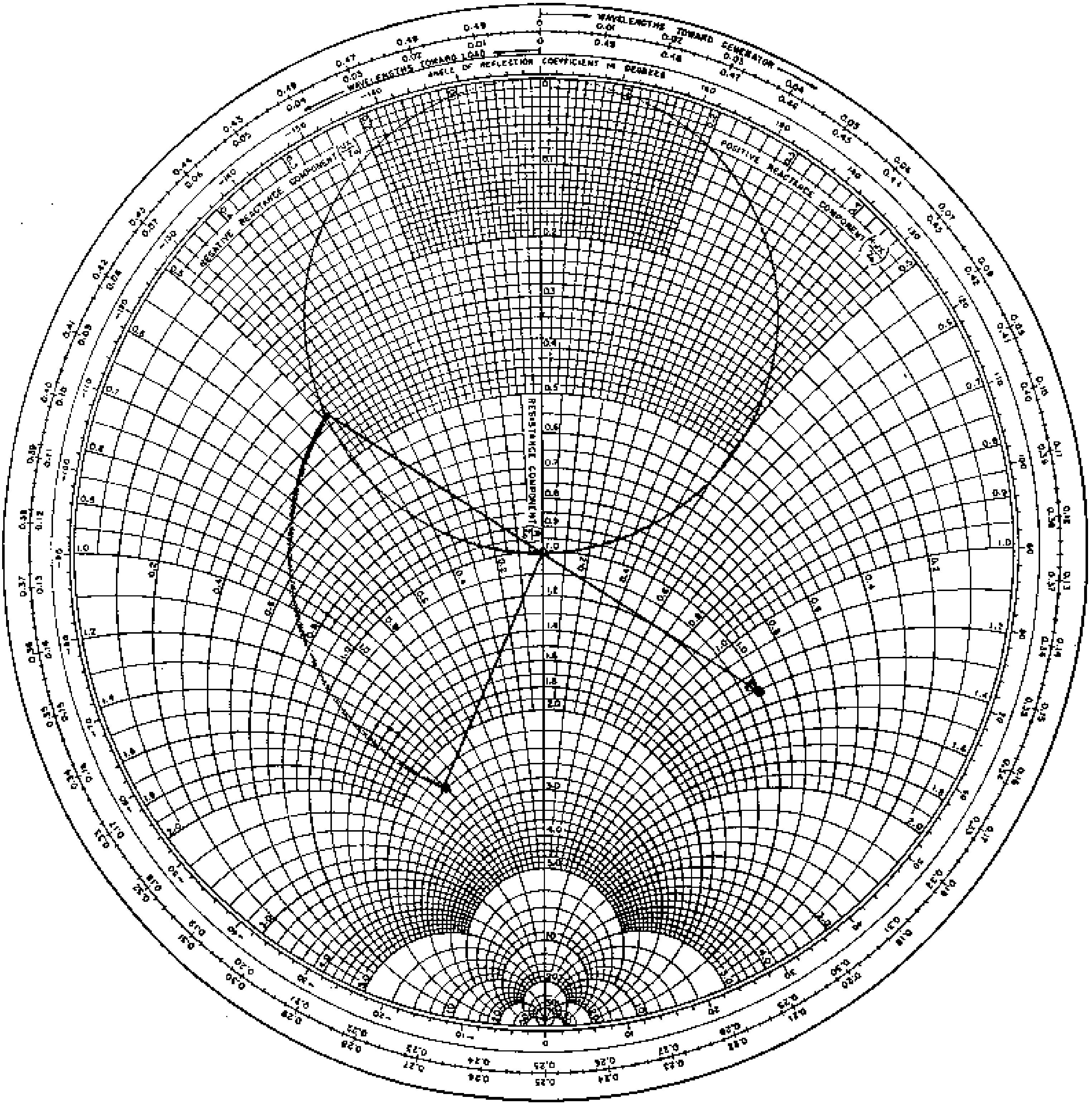
Smith Chart ②



Ref: Phillip H. Smith "Transmission Line Calculator" Electronics Jan. 1939 and Jan. 1944

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Smith Chart ③

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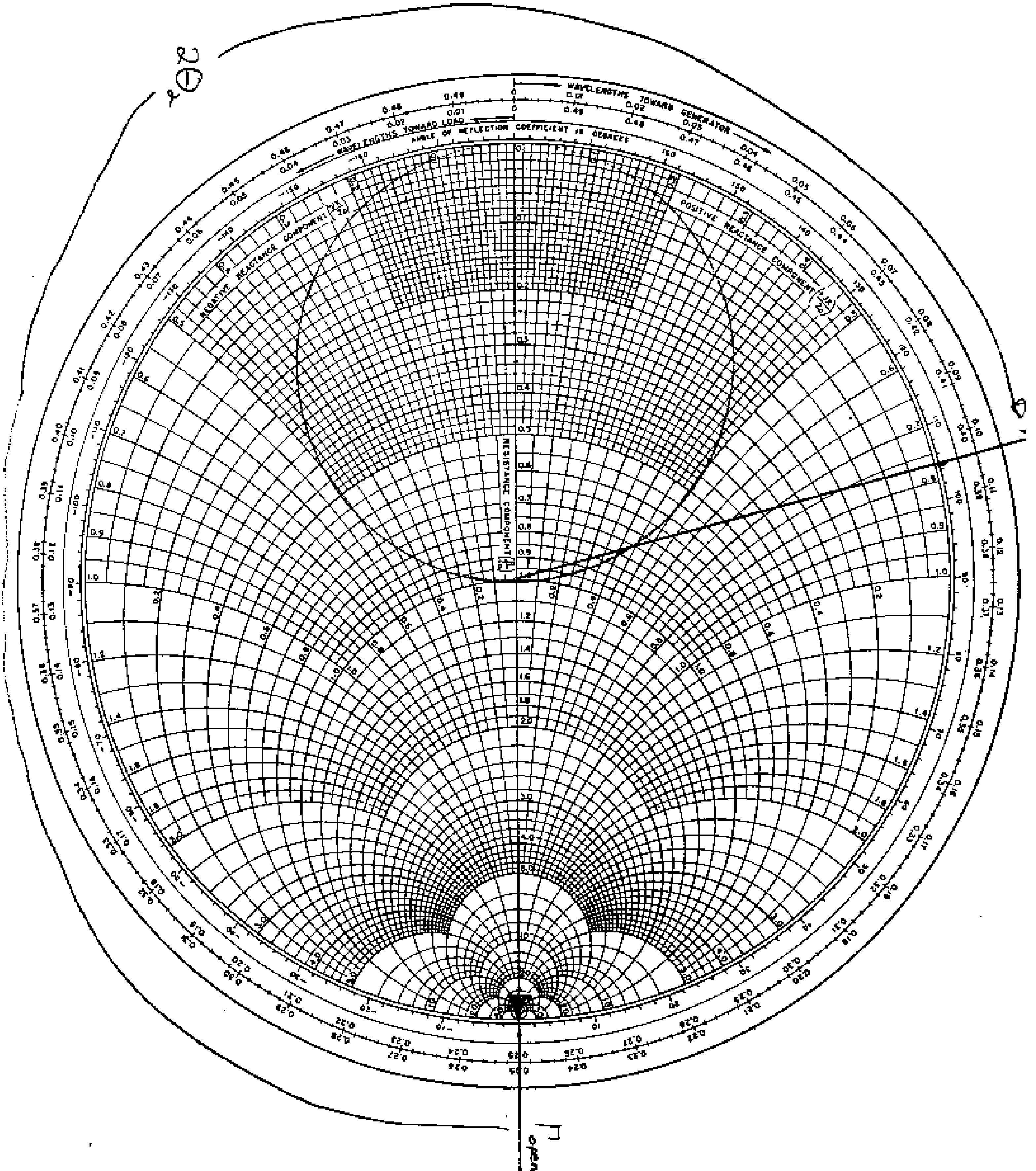

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14) Connect the delayed mystery load and the delayed open circuit together with a BNC Tee. Measure the complex impedance and reflection coefficient. Is $Z_{match} = 50\Omega$? Is $\Gamma_{match} = 0$?

15) Set the NWA to sweep from 50 to 70 MHz. Calibrate S_{11} with an OPEN response and attach the matched load. How broad band is the match. Sketch $\log|S_{11}|$ vs frequency. Sketch the frequency trajectory of S_{11} on a Smith Chart.

16) Try "tweeking" the match by adding or removing BNC barrels & bullets.

17) Repeat experiment for other mystery loads untill you are sick of this lab.

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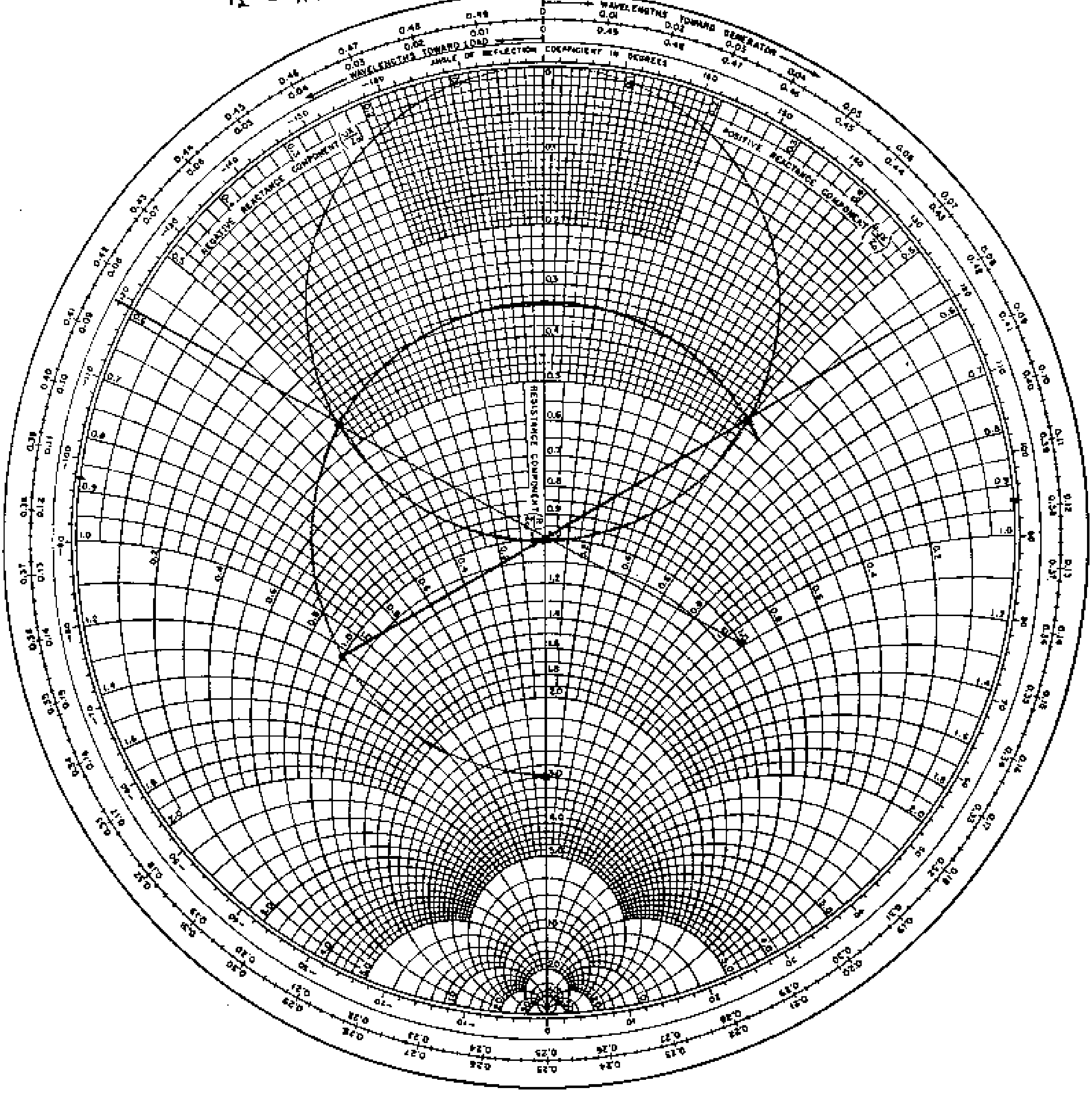
$150\,\Omega$

$2\theta_1 = 119°$
$\tau_1 = 3.3\,nS$
$y_p = -j1.08$
$Z_p = j.925$
$2\theta_2 = 336°$
$\tau_2 = 9.33\,nS$

$2\theta_1 = 240°$
$\tau_1 = 6.66\,nS$
$y_p = j1.15$
$z_p = -j.87$
$2\theta_2 = 97.5$
$\tau_2 = 2.7\,nS$



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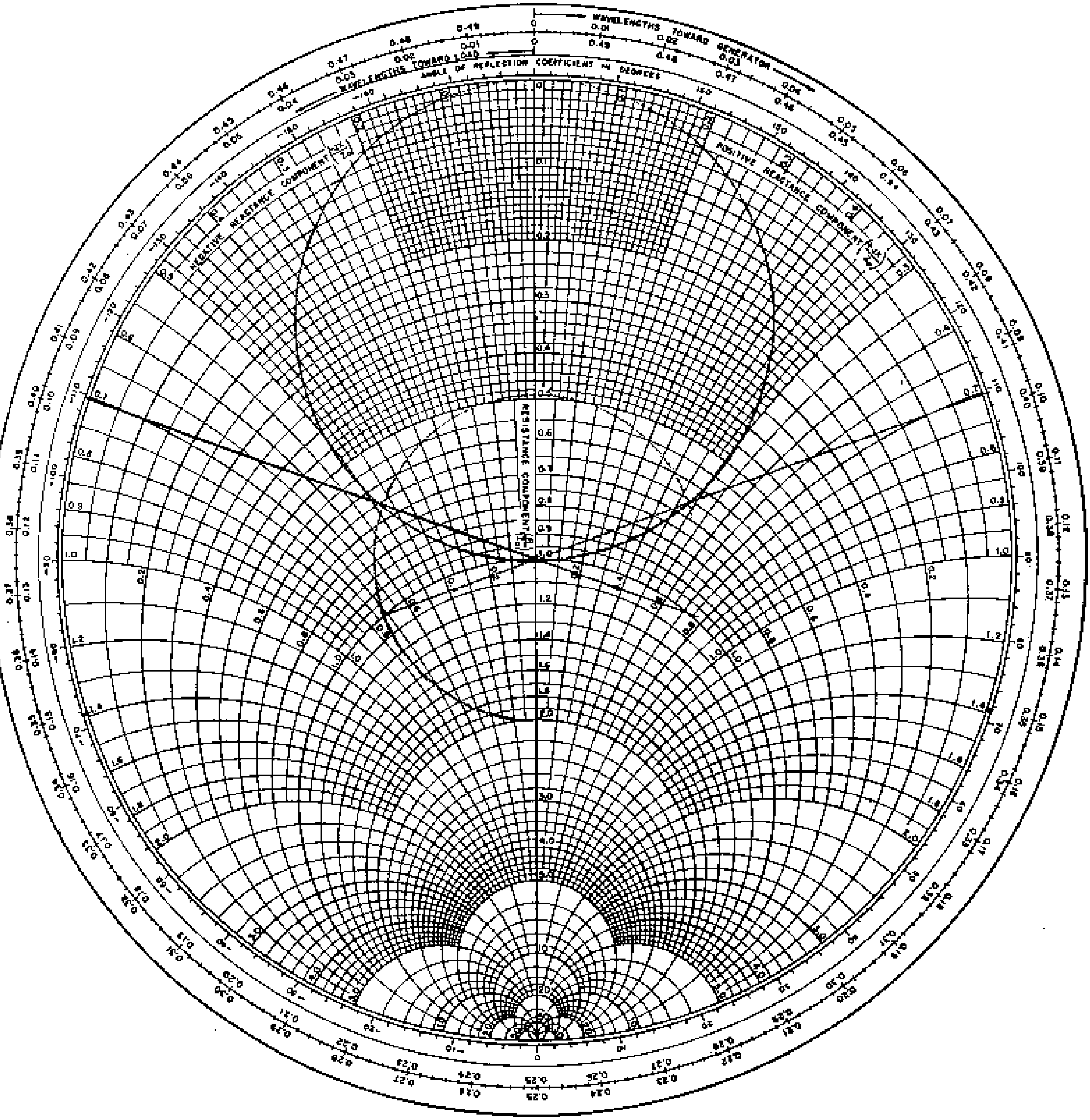
$2\theta_1 = 110^\circ$	$2\theta_1 = 250^\circ$
$\tau_1 = 3.05\,nS$	$\tau_1 = 6.94\,nS$
$Y_p = -j.72$	$Y_p = j.72$
$Z_p = j1.39$	$Z_p = -j1.4$
$2\theta_2 = 288.5$	$2\theta_2 = 71.5^\circ$
$\tau_2 = 8.01\,nS$	$\tau_2 = 1.98\,nS$

100Ω



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