Microwave Design Problems
Using Smith Chart

Prob. 1 $Z_L = 26 + j15 \Rightarrow 30 \angle 30^\circ$

$z_L = \frac{Z_L}{Z_0} = \frac{26 + j15}{50} = 0.52 + j0.3$

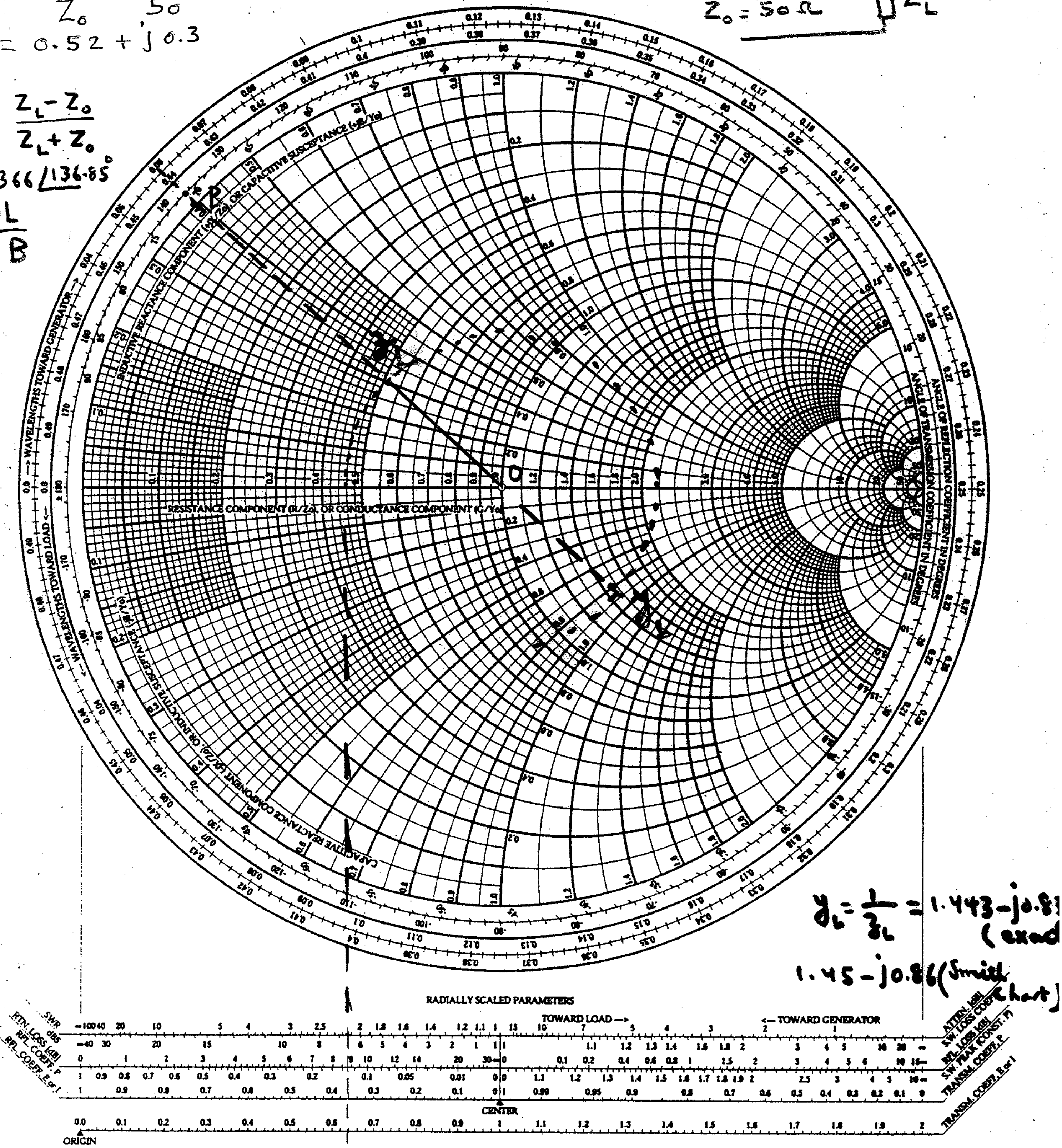
The Complete Smith Chart

Black Magic Design

$Z_0 = 50\,\Omega$ Z_L

$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = 0.366 \angle 136.85^\circ$

$\Rightarrow \frac{OL}{OB}$



$y_L = \frac{1}{z_L} = 1.443 - j0.8$ (exact)

$1.45 - j0.86$ (Smith Chart)

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$Z_L = 30\angle 30^\circ = 26 + j15\ \Omega$

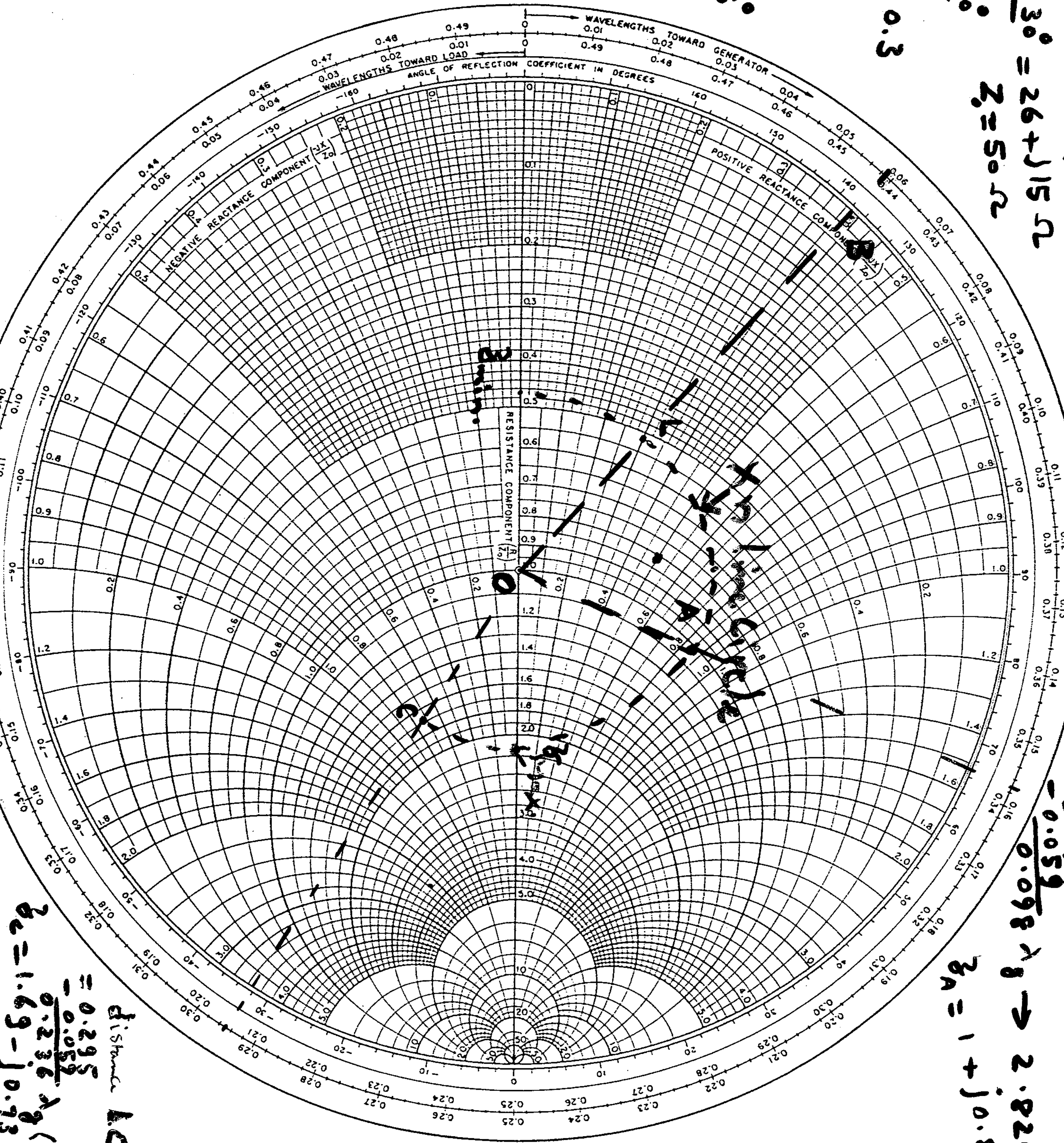
$Z_0 = 50\ \Omega$

$z_L = 0.6\angle 30^\circ$
$= 0.52 + j0.3$

$\rho = \frac{OL}{OB}$
$= 0.35\angle 137.5^\circ$

VSWR = 2.14

f = 800 MHz
$\lambda_0 = 37.5$ cm
$\lambda_g = \frac{\lambda_0}{\sqrt{\epsilon_{eff}}} = 28.76$ cm
1.7 → ϵ_{eff}



0.157
-0.059
$0.098\,\lambda_g \rightarrow 2.82$ cm
$z_A = 1 + j0.85$

distance LC
$= 0.295$
$- 0.059$
$0.236\,\lambda_g$ (6.79 cm)
$z_c = 1.69 - j0.93$

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

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Prob. 2

$Y_L = \frac{1}{30}\angle{-30^\circ}$

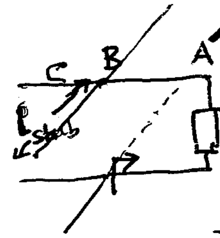
$f = 800\,MHz$

$\lambda_0 = 37.5\,cm$

$\lambda_g = \frac{\lambda_0}{\sqrt{\epsilon_{eff}}} = 28.76\,cm$

$\epsilon_{eff} \to 1.7$

$y_L = 1.443 - j\,0.833$



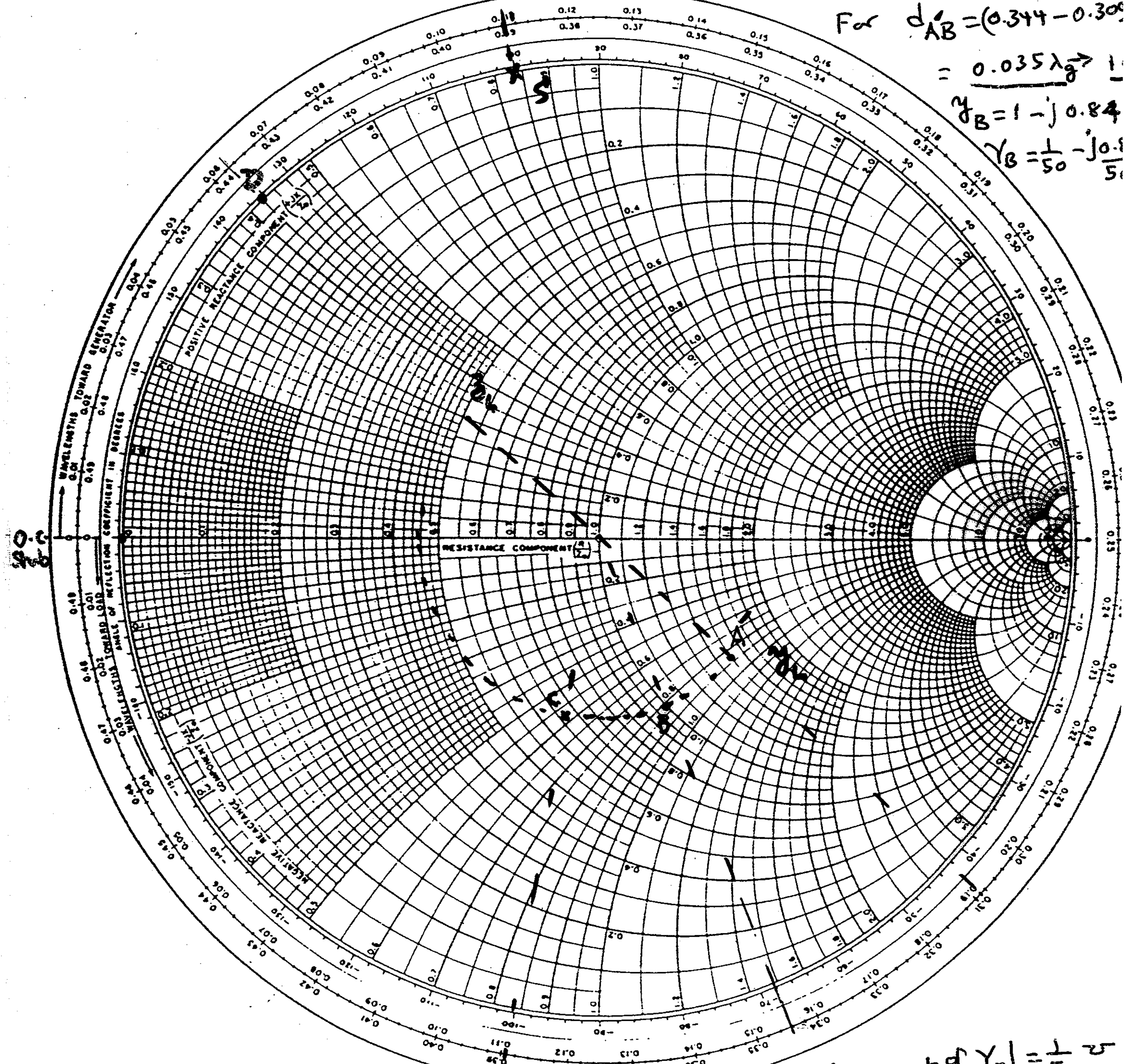
$Y_L = \frac{1}{30}\angle{-30^\circ}$

$y_L = \frac{Y_L}{Y_0} = 1.667\angle$

$\frac{1}{50} \to Y_0$

Fig. 2

"SMITH CHART"



For $d_{A'B} = (0.344 - 0.309$

$= \underline{0.035\,\lambda_g} \to$

$y_B = 1 - j\,0.84$

$Y_B = \frac{1}{50} - j\frac{0.8}{50}$

For shunt stub of $Y_0|_{stub} = \frac{1}{50}$ ℧

A. $\boxed{l_{sh} = 0.11\,\lambda_g}$ (Single-Sided Stub)

$\underline{31.64\,mm}$ $\quad j\,b_{sh} = +j\,0.84$

B. For double-sided Stub (D) $\quad j\,b'_{sh} = j\,0.42$

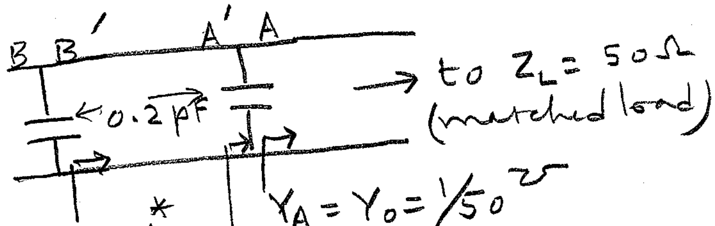
$l_{stub}|_{2\text{-Sided}} = 0.063\,\lambda_g \leftarrow \underline{18.1\,mm}$

Example 1

A microwave filter using two shunt capacitors

Take $f = 10\,GHz$

The normalized admittance at plane A' is shown on the accompanying Smith chart



$Y_A = Y_0 = 1/50$ ℧

$$y_{A'} = \frac{Y_A}{Y_0} = 1 + j\frac{\omega C}{Y_0} = 1 + j\,0.628$$

$$Y_{B'} = Y_{A'}^{*} = \frac{1}{50}(1 - j\,0.628)$$

$$Y_{A'} = Y_0 + j\omega C = Y_0\left(1 + j\frac{\omega C}{Y_0}\right) = \frac{1}{50}(1 + j\,0.628)$$

Moving from point A' to B' shown in the Smith chart, we get $Y_{B'} = Y_{A'}^{*} = Y_0 - j\omega C$

Upon adding an identical capacitor of 0.2 pF, we get the admittance Y_B at plane B to the left of the second capacitance

$$Y_B = (Y_0 - j\omega C) + j\omega C = Y_0$$

the transmission line to the left of plane B is matched.

Thus the distance $l_{A'B'} = 2(0.25 - 0.149)\lambda_g = 0.202\lambda_g$ (from Smith chart)

In the following example, we redo this problem using a higher characteristic impedance $Z_0' = 75\,\Omega$ between the two capacitors.

10¢

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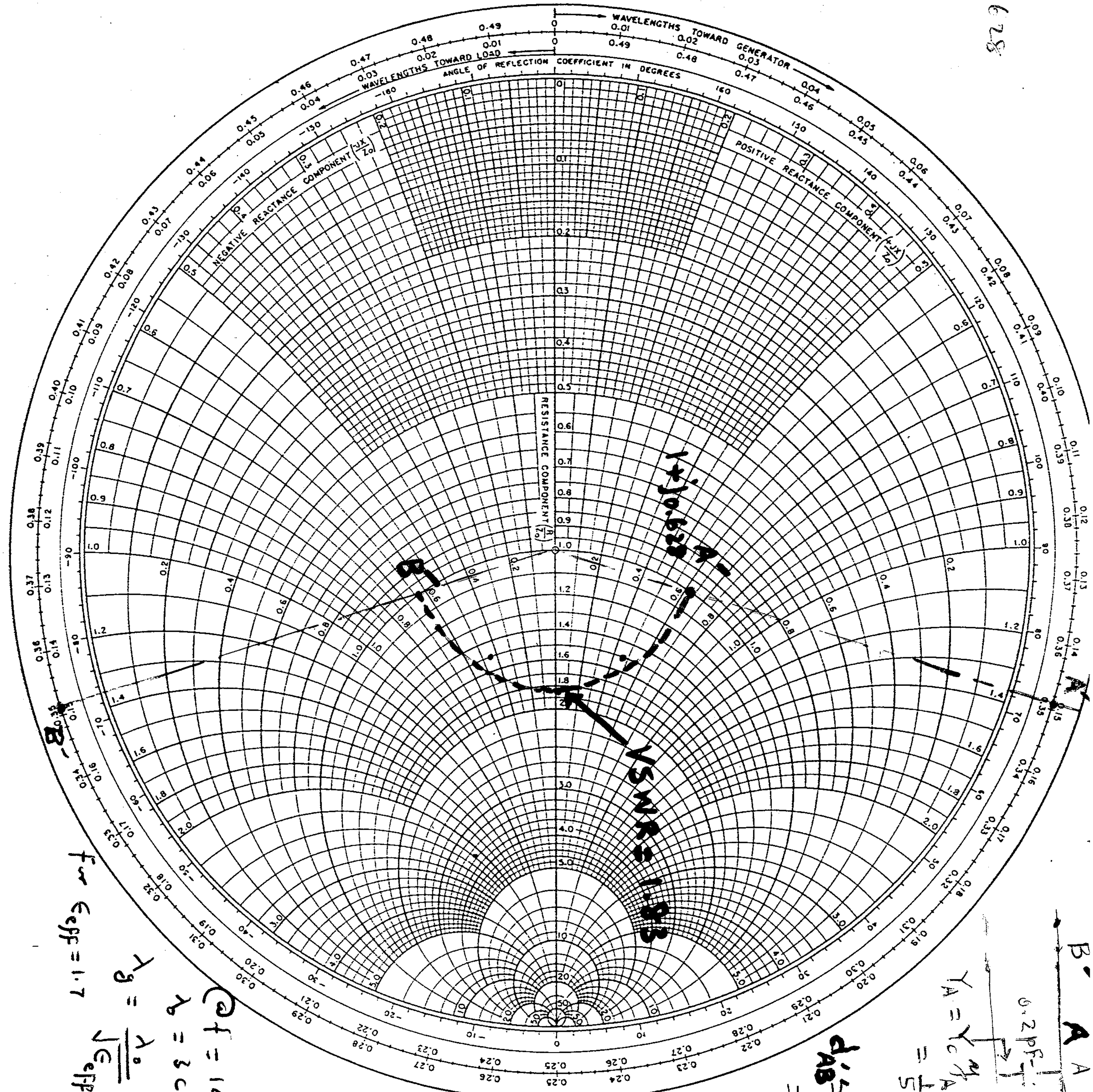
$y_L = 1 + j\,0.628$



@ $f = 10\,\text{GHz}$

$\lambda_0 = 3\,\text{cm}$

$\lambda_g = \dfrac{\lambda_0}{\sqrt{\epsilon_{eff}}} = 2.3\,\text{cm}$

for $\epsilon_{eff} = 1.7$

B A

$Y_A = Y_c\, y_A = \frac{1}{50}(1 + j0.628)$

$d'_{AB} = 2(0.25 - 0.149)\lambda_g$

$= 0.202\,\lambda_g$

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

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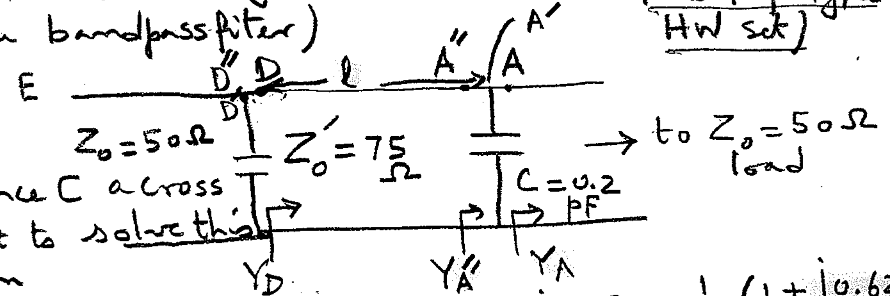
A matching circuit using two appropriately spaced capacitors (Similar to Prob. 4 of Typed HW set)
(this can also be used as a bandpass filter)

Ex. $f = 10\ GHz$
$C = 0.2\ pF$



Because of the shunt capacitance C across the transmission line, it is best to solve this as an admittance problem

$$Y_A = \frac{1}{Z_0} = \frac{1}{50}\ ℧ \ ; \quad Y_{A''} = Y_A + Y_{A'} = Y_A + j\omega C = \frac{1}{50}(1 + j0.628)$$

$$y_{A''} = \frac{Y_{A''}}{Y_0'} = \frac{\frac{1}{50}(1 + j0.628)}{1/75} = 1.5 + j0.942$$

the effective normalized "load" to the $Z_0' = 75\Omega$ line is point A'' in Fig. 3.

a. After traversing a distance $l = 0.2\lambda_g$ to a plane D of the Xn line

$$y_D\Big| = 0.625 - j0.575$$
from Fig. 3

For actual admittance $\quad Y_D = Y_0'(0.625 - j0.575) = \frac{1}{75}(0.625 - j0.575)$

At point D' we connect a second capacitor $C = 0.2\ pF$; $Y_{D'} = j\omega C$

$$Y_{D''} = Y_D + Y_{D'} = \frac{1}{75}(0.625 - j0.575 + j0.3\pi) = \frac{1}{75}(0.625 + j0.367)$$

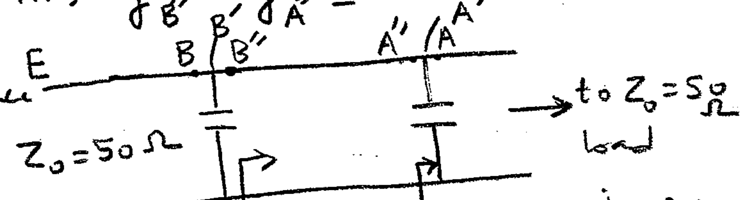
This is the effective "load" to the section D''E of the Xn line with $Z_0 = 50\ \Omega$

$$y_{D''} = \frac{Y_{D''}}{Y_0} = 50\,Y_{D''} = 0.417 + j0.295$$

This is shown as point D'' in Fig. 3. We can draw a transmission line circle with radius OD''. This will intercept the positive x-axis at point E (in Fig. 3)
Thus VSWR for the transmission line to the left of point D'' is 2.6.
$|\Gamma| = \frac{SWR - 1}{SWR + 1} = 0.444$

b. In order to match the transmission line, we move to a point B'' for which $y_{B''}$ is complex conjugate of $y_{A''}$. Thus $y_{B''} = y_{A''}^* = 1.5 - j0.942$

Why?



Upon adding a second identical capacitance

$$Y_B = Y_{B''} + j\omega C$$
$$= Y_0'\,y_{B''} + j\omega C = \frac{1}{75}(1.5 - j0.942) + j\omega C$$
$$= \frac{1}{50} + j0$$

$y_{B''} = y_{A''}^* = 1.5 - j0.942 \qquad y_{A''} = 1.5 + j0.942$

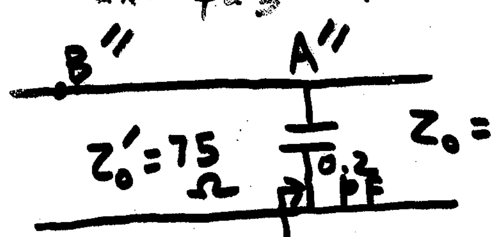
and the line is matched for all points of the transmission line to the left of point B

From Smith chart Fig. 3

length $l_{A''B''} = (0.307 - 0.193)\lambda_g = \boxed{0.114\ \lambda_g} = 0.114 \frac{\lambda_0}{\sqrt{\epsilon_{eff}}} = 2.62\ mm$

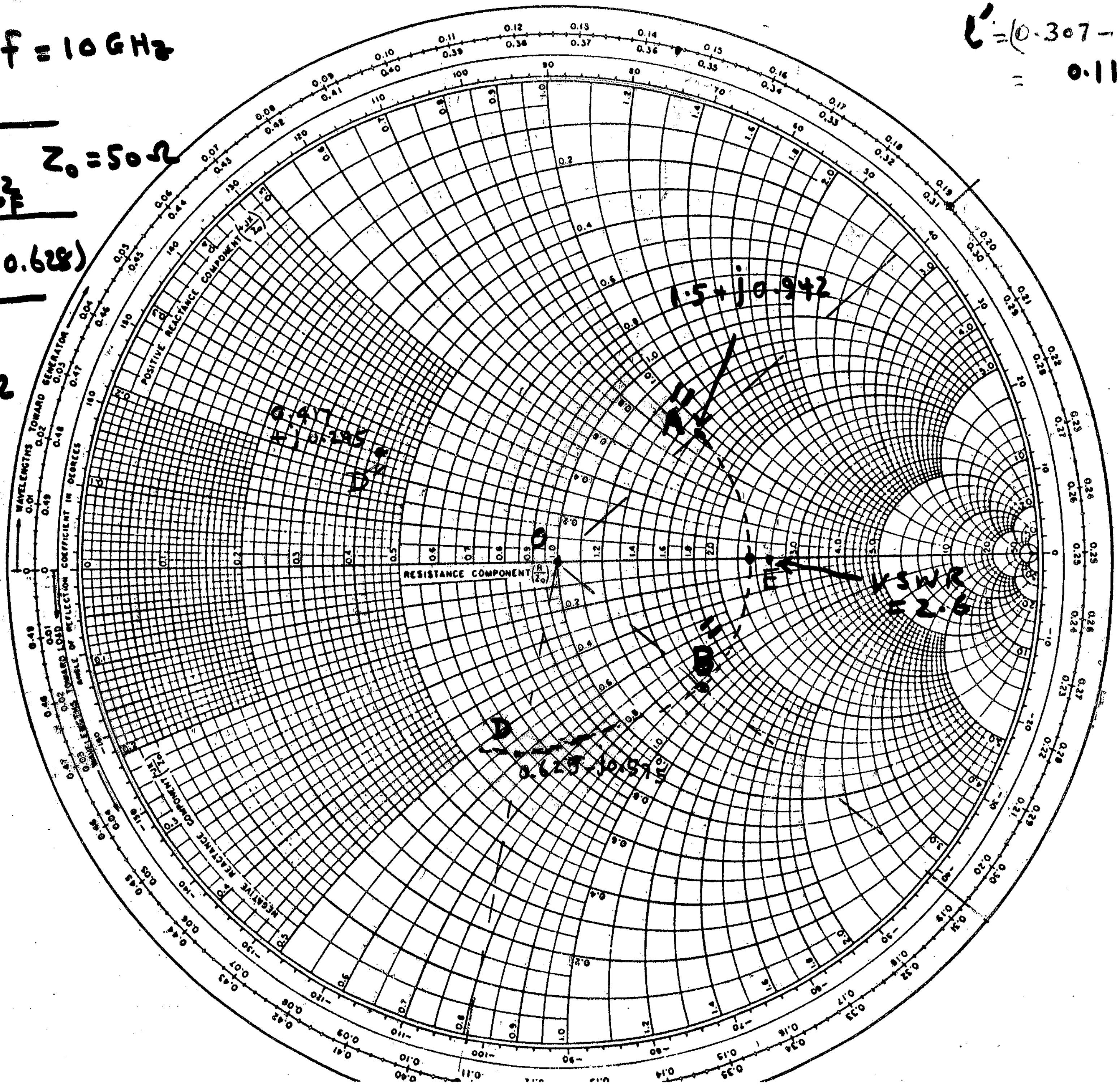
1.7

Example 3 $f = 10\,GHz$



$$y_{A'} = \frac{\frac{1}{50}(1 + j0.628)}{1/75} = 1.5 + j0.942$$

$d_{A''B''} = \ell'$



$\ell' = (0.307 - 0.193) = 0.114\,\lambda_g$

Fig. 5