TEXT SECTION 5.3

YOU WILL NEED - COMPASS

HOMEWORK - DUE WED.

DEMO - TLINE

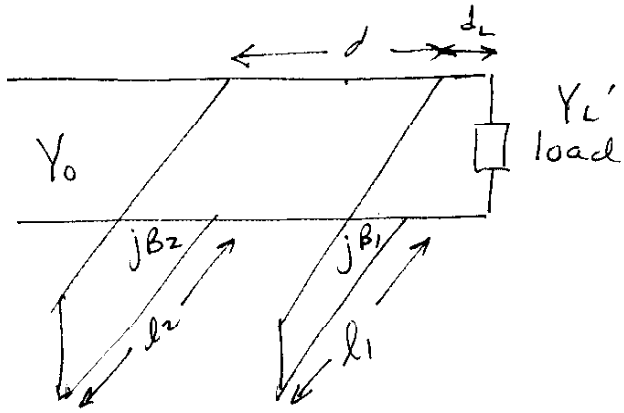
DOUBLE STUB MATCHING

Use 2 stubs

Keep distances d_L and d constant

Change lengths of stubs to match/tune

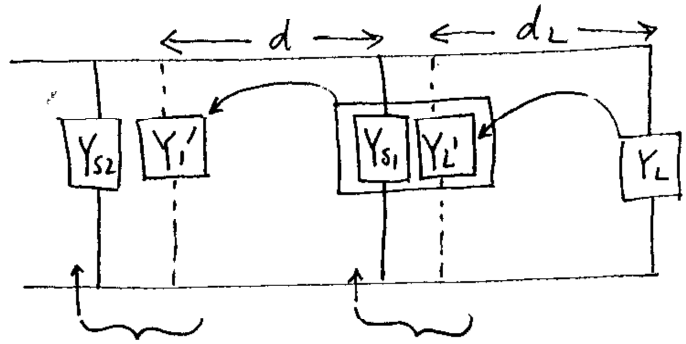
* Ideal for tunable matching circuit



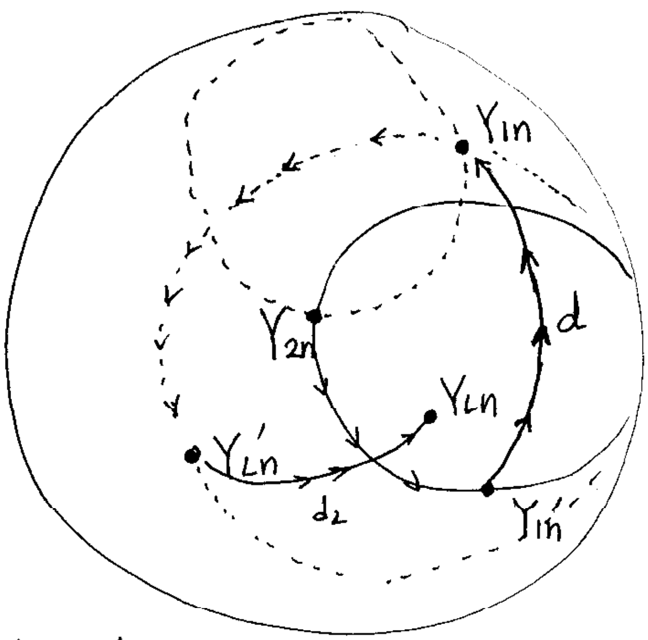
- parallel stubs easiest for microstrip
- short ckt. terminations also easiest
- easiest to analyze shunts w/ Y

Dstub
13
1X-01

To Understand this, let's work backwards



$1+j0 = Y_2 = Y_{S2} + Y_1'$ $\quad$ $Y_1 = Y_{S1} + Y_L'$



Backward:

(1) $Y_{2n} = 1 + j0$ (matched)

(2) $Y_{1n}' = Y_{2n} - Y_{S2_n} = 1 - jX_{S2_n}$

$\uparrow$ strictly imaginary $= jX_{S2_n}$

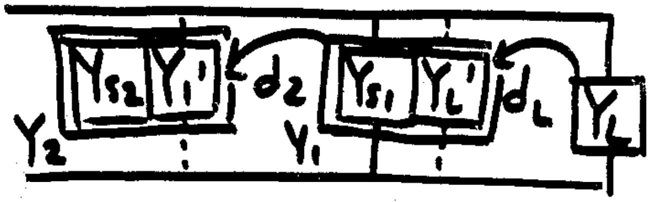
(3) Rotate TWL distance d to Y_{in}

(4) $Y_{Ln}' = Y_{in} - Y_{S1_n} = (G_{in} + jX_{in}) - jX_{S1_n} = G_{in} + j(X_{in} - X_{S1_n})$

$\uparrow$ strictly imaginary $= jX_{S1_n}$

Move along constant G circle to $j(X_{in} - X_{Sin})$

(5) Rotate TWL to Y_{Ln} distance d_2

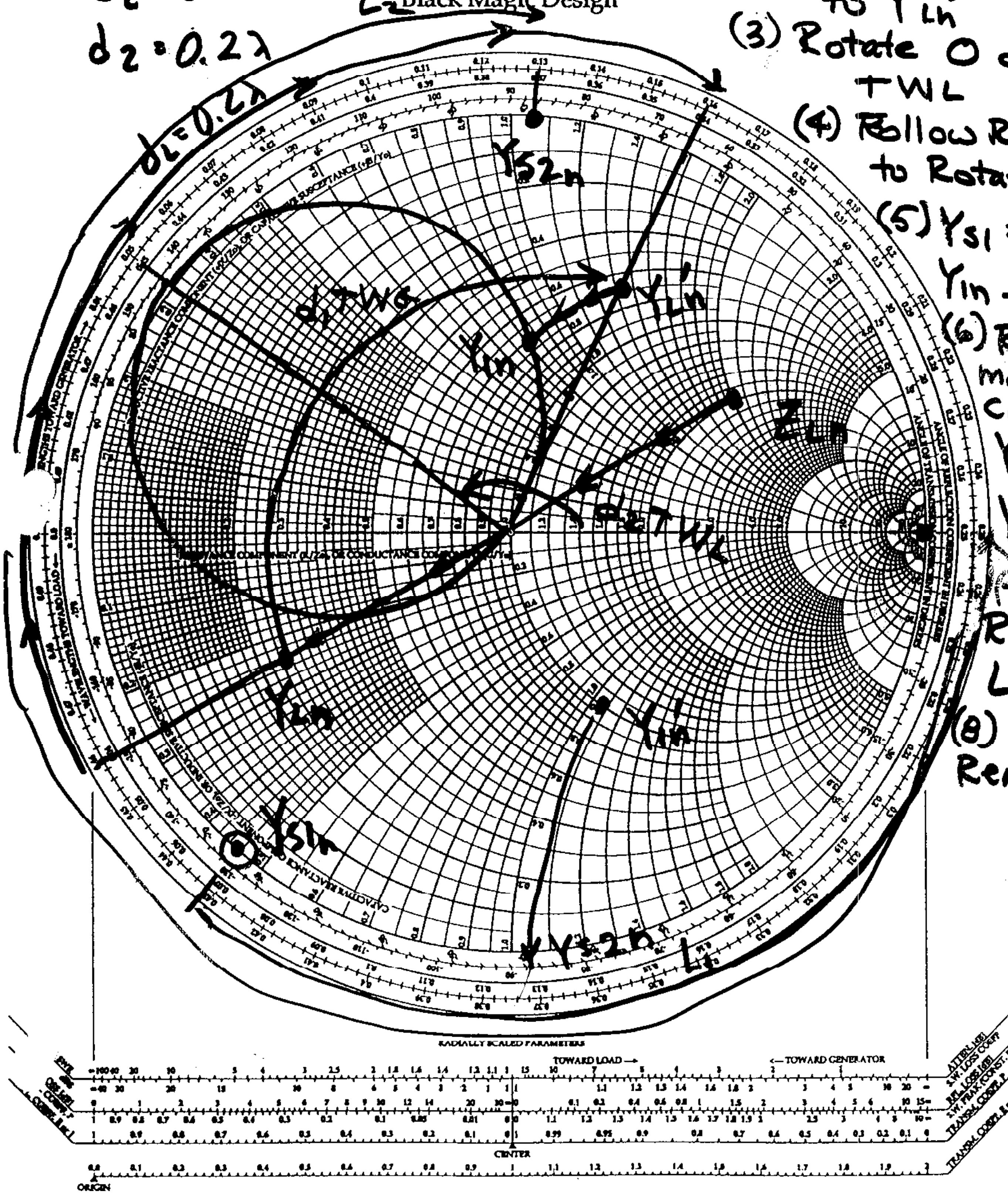


Double Stub Match

(1) Plot $Z_{Ln} \to Y_{Ln}$
(2) Rotate d_1 TWG to Y_{Ln}'
(3) Rotate O d_2 TWL
(4) Follow Real to Rotated O
(5) $Y_{S1} = Y_{in} - Y_{Ln}'$
(6) Rot. match circle Y_{in}' Y_{short}
(7) Read L_1 Y_{S2}
(8) Remove

The Complete Smith Chart

$d_L = 0.2\lambda$
$d_2 = 0.2\lambda$



Forward: Design Double Stub tuner

(1) Normalize and plot Z_{Ln}. Convert to Y_{Ln}

(2) Rotate TWG distance d_2 to Y_{Ln}'

(3) Draw matching circle rotated d TWL

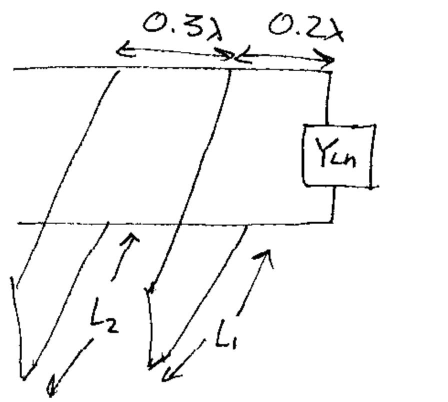
(4) Move along constant G (real part) TWG to rotated matching circle Y_{in}

(5) $Y_{s1n} = Y_{1n} - Y_{Ln}'$. Plot. Rotate TWL to Y_{short}. $\rightarrow L_1$

(6) Rotate d TWG to Y_{1n}'

(7) $Y_{s2n} = Y_{2n} - Y_{1n}'$. Plot. Rotate TWL to $Y_{short} \rightarrow L_2$

Example



(1) $Z_L = 100 + j100\ \Omega$, $Z_0 = 50\ \Omega$ $\Big\rangle$ $Z_{Ln} = 2 + j2$, Rotate to Y_{Ln}

(2) Rotate 0.2λ TWG to Y_{Ln}'

(3) Draw matching circle 0.3λ TWL

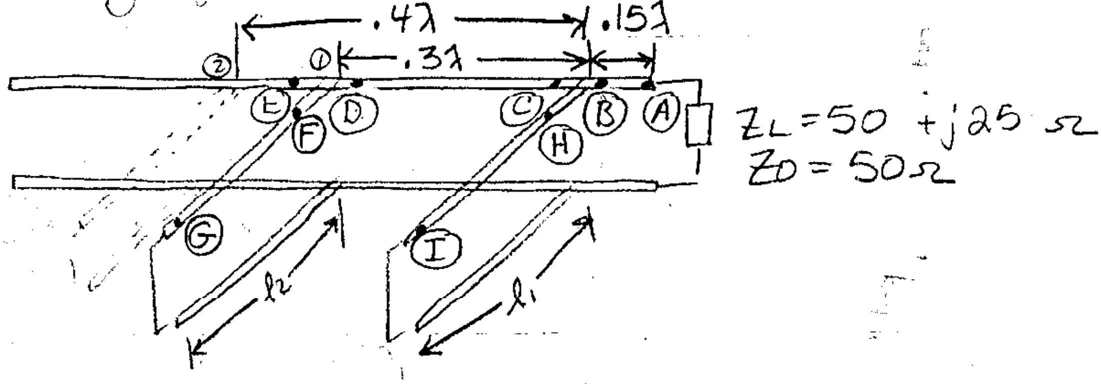
(4) Move along constant $G = 0.725$ to rotated matching circle Y_{in}

(5) $Y_{s1n} = Y_{1n} - Y_{Ln}' = (G + j0.85) - (G + j1.3) = -j0.45$
Plot Y_{s1n}. Rotate TWL to Y_{short}. $L_1 = 0.43 - 0.25\,\lambda = 0.18\lambda$

(6) Rotate d TWG to $Y_{1n}' = 1 - j1.05$

(7) $Y_{s2n} = Y_{2n} - Y_{1n}' = (1 + j0) - (1 - j1.05) = j1.05$
Plot Y_{s2n}. Rotate TWL to Y_{short}. $L_2 = 0.5 - (0.37 - 0.25)$
$=$

(#1.20) ... is shown below. The position of the fi... stub is ... at .15λ from the B-B′ port, and the other stub may be lo... either at position 1, 0.3λ from the first stub, or at position 2, 0.4λ from the first stub. Determine which of positions 1 or 2 are suitable for matching and the lengths of the stubs necessary for either position.



1) Plot $Z_{AN} = \dfrac{50 + j25}{50} = 1.0 + j.5$ Point A

2) Convert to Y_{AN} Point A

3) Rotate 0.15λ toward generator on constant $|\Gamma|$ circle to Point B $Y_{NB} = .63 + j.175$

4) Draw two rotated matching circles, rotating 0.3λ and 0.4λ toward the load from Oc

5) Move B along constant conductance circle toward generator until it intersects the rotated matching circle. Plot Points C1 C2
Read $Y_{NC1} = .63 + j.24$
$Y_{NC2} = .63 + j2.6$

6) Rotate 0.3λ and 0.4λ toward generator along $|\Gamma|$ circles. Points D1 and D2 should be on regular matching circle.
Read $Y_{ND1} = 1.0 - j0.55$
$Y_{ND2} = 1.0 + j3.2$

7) Match @ E-D so $Y_{NE} = 1.0 + j0.0$ (center of chart)
$\left.\begin{array}{l} Y_{NF1} = +j0.55 \\ Y_{NF2} = -j3.2 \end{array}\right\}$ Plot F1 and F2
(toward load)

8) Rotate along constant $|\Gamma|$ circle, to $Y_{NG} = \infty$ (shor...
$\boxed{\text{case 1: } l_2 = .75\lambda - .42\lambda = 0.33\lambda}$

$\boxed{\text{case 2: } l_2 = .25\lambda - .202\lambda = .048\lambda}$

9) Now match at C-B:

$g_H = g_C - g_B$

$g_{H1} = .24 - .175 = .065$ Plot H1 $j.065$

$g_{H2} = 2.6 - .175 = 2.425$ H2 $j2.425$

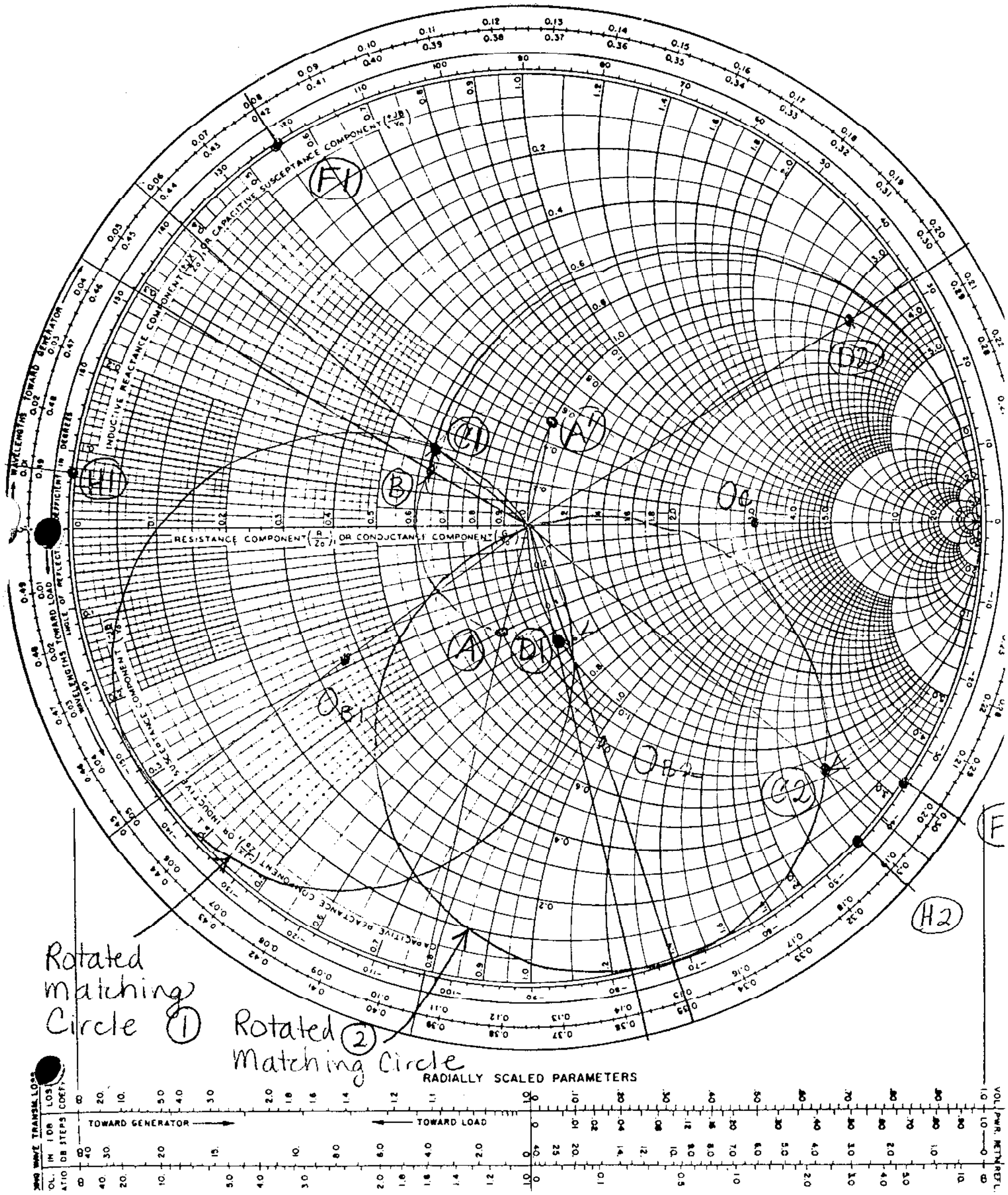
10) Rotate toward load along constant $|\Gamma|$ circle until reach $Y_{N1} = \infty$ (short circuit).

$\boxed{\begin{array}{l}\text{case 1: } l_1 = .75\lambda - .49\lambda = 0.26\lambda \\ \text{case 2: } l_1 = .25\lambda - .189\lambda = 0.061\lambda\end{array}}$

(*) either position 1 or 2 can be used.

352	TITLE HW#5 Prob. #7.28	DWG. NO.
CHART FORM 5301-7560-N	GENERAL RADIO COMPANY, WEST CONCORD, MASSACHUSETTS	DATE

IMPEDANCE OR ADMITTANCE COORDINATES



EM Fields + Waves
MF Iskander

7.14.3 Double-Stub Matching

A serious practical limitation of the single-stub matching procedure is varying the location of the stub d_1 for each different load impedance. The double-stub matching method overcomes precisely this problem by changing the adjustable unknown variables from being the location and the length of the stub to the unknown lengths of two stubs located at fixed distances from each other and from the load. In the double-stub matching procedure, shown in Figure 7.52, therefore, the distance between the stubs is known, and it is required to determine the lengths d_1 and d_2 of the two stubs.

To help us understand the solution procedure, the following points should be noted:

1. The admittance just after the second stub $\hat{Y}_{B^+}$ should be equal to the characteristic admittance of the main line $Y_o = 1/Z_o$. This way the reflection coefficient will be zero, and the desired impedance matching would be achieved. The normalized admittance just after the second stub $\hat{y}_{nB^+}$ is, hence, equal to 1, which is located at the origin B^+ of the Smith chart shown in Figure 7.53.

2. The admittance of the short-circuited stub is purely susceptance. Hence, the normalized admittance $\hat{y}_{nB^-}$, just before the second stub should lie on the $g = 1$ circle, known as the *matching circle*. The specific location of $\hat{y}_{nB^-}$ on the matching circle is, however, unknown and depends on the specific value of the susceptance of the stub, which is to be determined.

3. The admittances $\hat{y}_{nB^-}$ and $\hat{y}_{nA^+}$ just before the second stub and just after the first stub, respectively, are separated by a section of length d (known) of *lossless* transmission line. The specific value of $\hat{y}_{nA^+}$ may, therefore, be obtained from $\hat{y}_{nB^-}$ by rotating $\hat{y}_{nB^-}$ a distance (d) toward the load (counterclockwise). Because the specific

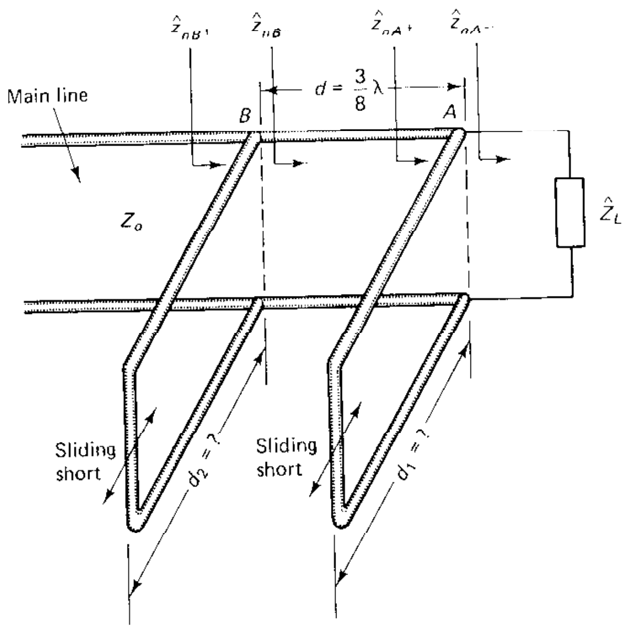


Figure 7.52 The double-stub matching arrangement. The distance between the stubs is given, and it is required to determine d_1 and d_2 to achieve matching.

value of $\hat{y}_{nB^-}$ is not known on the matching circle, however, we obtain a locus for $\hat{y}_{nA^+}$ by rotating the whole matching circle a distance d toward the load.

Graphically, this may be achieved by rotating the origin of the matching circle a distance d and drawing a circle of the same radius at the new origin. The new circle is the locus of $\hat{y}_{nA^+}$ and is known as the *rotated circle*.

4. The first stub is also a short-circuited section of transmission line and, hence, provides a susceptive value of admittance. The difference between $\hat{y}_{nA^-} = \hat{y}_{nL}$ and $\hat{y}_{nA^+}$ is simply the susceptance of the first stub. The specific value of $\hat{y}_{nA^+}$ may then be obtained from $\hat{y}_{nL}$ by moving along the *constant conductance*, g = *constant, circle* from $\hat{y}_{nL}$ until it intersects the rotated circle.

The susceptance for stub 1 is therefore chosen to alter the admittance from $\hat{y}_{nL}$ at point A^- (Figure 7.53) to $\hat{y}_{nA^+}$ at A^+ on the rotated circle. The corresponding point just to the right of stub 2 is obtained by rotating point A^+, on the rotated circle, a distance $d = 3\lambda/8$ toward the generator. This procedure will result in point B^- shown in Figure 7.53. The stub length d_2 is chosen to modify the admittance at B^- to $\hat{y}_{nB^+} = 1$, thus producing a matched transmission-line system. Stub lengths required to provide the necessary susceptances are found by moving around the chart perimeter $g = 0$ circle from the short-circuit position ($y_n = \infty$) to the desired normalized admittance value.

The step-by-step procedure for double-stub matching is summarized as follows:

1. Draw the rotated circle by rotating the matching circle $g = 1$ an angle $2\beta d$ toward the load, where d is the known distance between the two stubs.

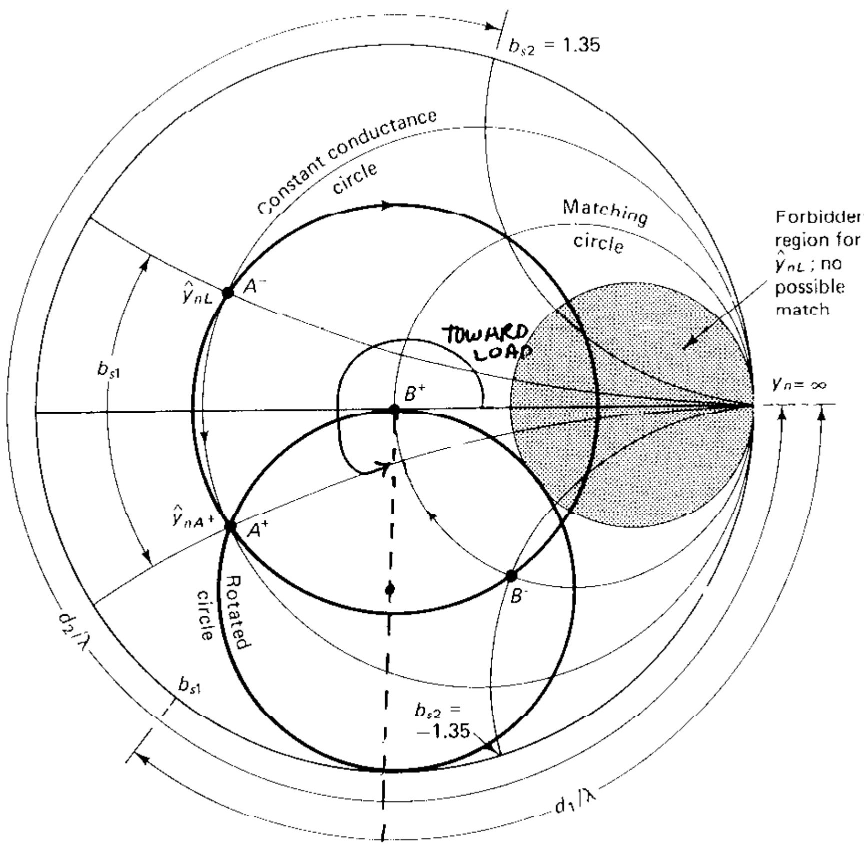


Figure 7.53 Double-stub matching solution procedure.

2. Locate the normalized load admittance $\hat{y}_{nL}$ on the Smith chart.
3. Follow the constant conductance locus g = constant on the Smith chart to the point where it intersects the rotated circle. The admittance at this point is $\hat{y}_{nA^+} = \hat{y}_{nL} + jb_{s1} = g_L + jb_1$, where $b_{s1} = b_1 - b_L$, b_1 is the susceptance at $\hat{y}_{nA^+}$, and b_L is the load normalized susceptance (imaginary part of $\hat{y}_{nL}$).
4. Because b_1 and b_L are known, the required susceptance of the first stub can be determined and the length of the stub d_1 may hence be calculated.
5. From $\hat{y}_{nA^+}$, follow the $|\hat{\Gamma}|$ = constant circle a distance $2\beta d$ until it intersects the matching circle at $\hat{y}_{nB^-}$. The susceptance of the second stub is then chosen to obtain matched system immediately after the stub. If the normalized admittance immediately to the right of stub 2 is $\hat{y}_{nB} = 1 + jb_2$, the normalized susceptance of stub 2 should therefore be $b_{s2} = -b_2$. The length of the second stub is obtained using a procedure similar to that in step 4.

EXAMPLE 7.15 DOUBLE STUB MATCH

The layout for a double-stub tuner is shown in Figure 7.54. Determine the required lengths of stubs d_1 and d_2.

Solution

The step-by-step solution is as follows:

1. Draw the matching circle ($g = 1$ circle) and the rotated circle (0.25λ toward the load away from the matching circle) as shown in Figure 7.54.
2. Plot the load normalized admittance $\hat{y}_{nL}$ on the Smith chart (point A).
3. Move on a constant reflection coefficient circle a distance of 0.1λ toward the generator to point B. The normalized admittance $\hat{y}_{nB} = 0.6 - j0.685$.
4. At point B, we insert the first stub. Hence, the admittance just before and just after the stub should have the same conductance. We therefore move from B on the constant conductance line until we intersect the rotated circle at point C. The normalized admittance $\hat{y}_{nC} = 0.6 - j0.5$.
5. Because the admittance $\hat{y}_{nC}$ just after the first stub and the admittance, say $\hat{y}_{nD}$, just before the second stub are separated by a 0.25λ section of a transmission line, $\hat{y}_{nD}$ may be obtained by rotating $\hat{y}_{nC}$ on a constant reflection coefficient circle a distance 0.25λ toward the generator or until the constant $|\hat{\Gamma}|$ circle intersects the matching circle at D. The normalized admittance $\hat{y}_{nD} = 1 + j0.81$.
6. The susceptance of the second stub is required to change the admittance at D, $\hat{y}_{nD}$, to that at the matching point at the center of the Smith chart O.
7. From Figure 7.54, the normalized susceptance of the first stub is given by

$$\hat{y}_{ns_1} = \hat{y}_{nC} - \hat{y}_{nB} = j0.185$$

   The normalized susceptance of the second stub is

$$\hat{y}_{ns_2} = 1.0 + j0 \text{ (at matching point } O) - \hat{y}_{nD} = -j0.81$$

8. The length of each stub is determined by rotating from the short-circuited end of each stub ($y_n = \infty$) along the rim of the Smith chart ($g = 0$ circle) toward the generator, sufficient distances (i.e., lengths of the stubs) so as to obtain the desired values of the admittances of these stubs. From Figure 7.54, it can be seen that the length of the first stub $d_1/\lambda = 0.278$, whereas the length of the second stub $d_2/\lambda = 0.142$.

7.15 VOLTAGE STANDING-WAVE RATIO (VSWR) ALONG TRANSMISSION LINES

In chapter 5 when we discussed reflections of plane waves, it was indicated that as a result of the interference between the incident and the reflected waves that are propagating in opposite directions and of the same frequency, there will be standing waves. An amplitude maxima occurs whenever there is a constructive interference in which

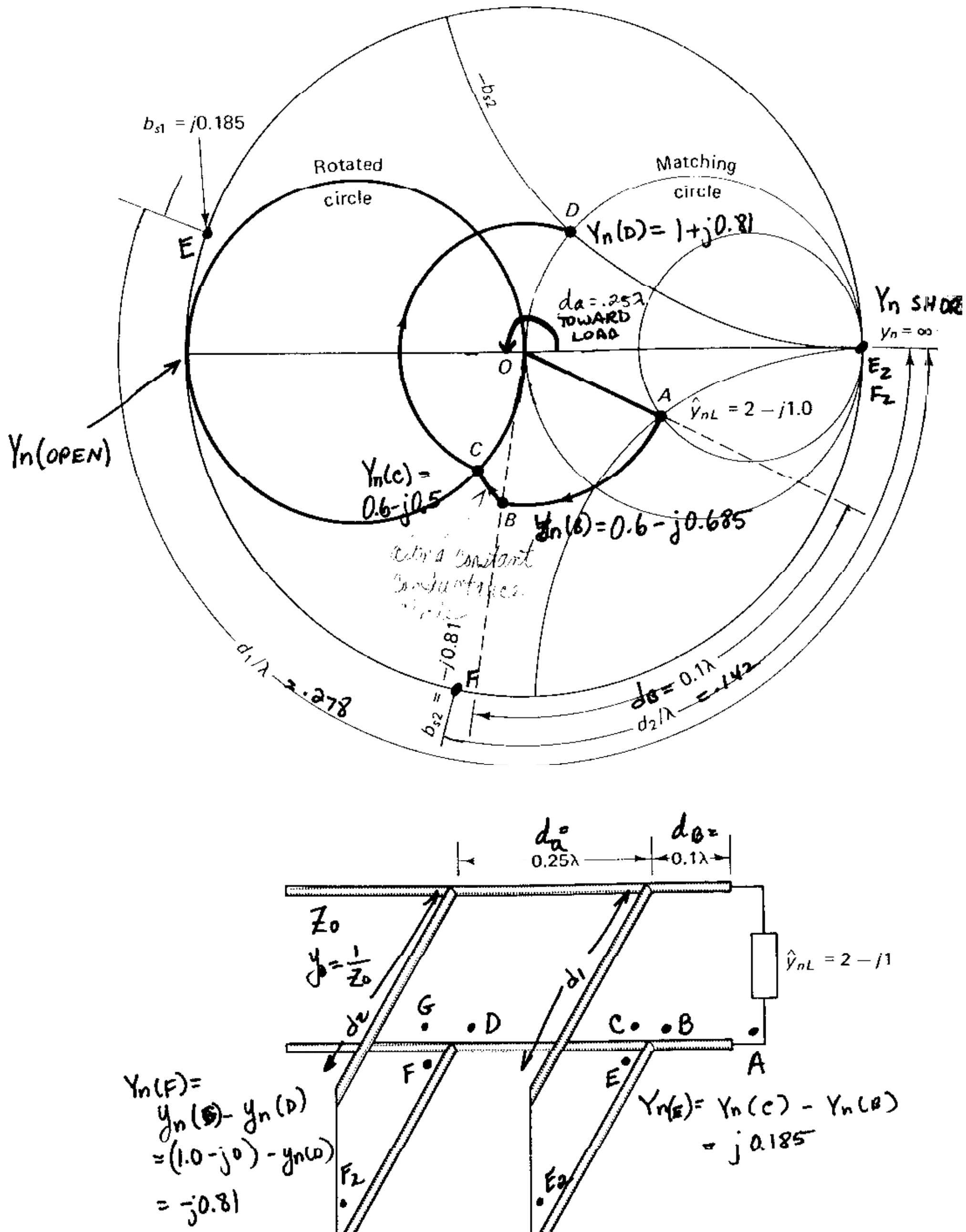


Figure 7.54 Double-stub matching solution of example 7.15.