Transmission Line Matching Techniques

Smith Chart and Impedance Matching:

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = |\Gamma_L| e^{j\theta_L} = \Gamma_r + j\Gamma_i$$

Since $|\Gamma_L| \leq 1$, the value of Γ_L must lie on or within the unit circle.

Define the normalized impedance as,

$$z = \frac{Z}{Z_0} = \frac{1+\Gamma}{1-\Gamma} = \frac{R+jX}{Z_0} = r + jx$$

then $\Gamma = \frac{z-1}{z+1} = \Gamma_r + j\Gamma_i$ and thus,

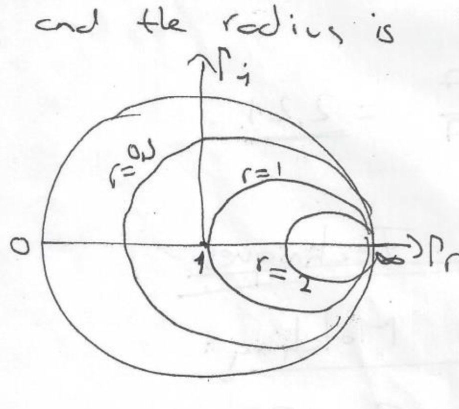
$$r = \frac{1-\Gamma_r^2-\Gamma_i^2}{(1-\Gamma_r)^2+\Gamma_i^2} \quad \text{and} \quad x = \frac{2\Gamma_i}{(1-\Gamma_r)^2+\Gamma_i^2}$$

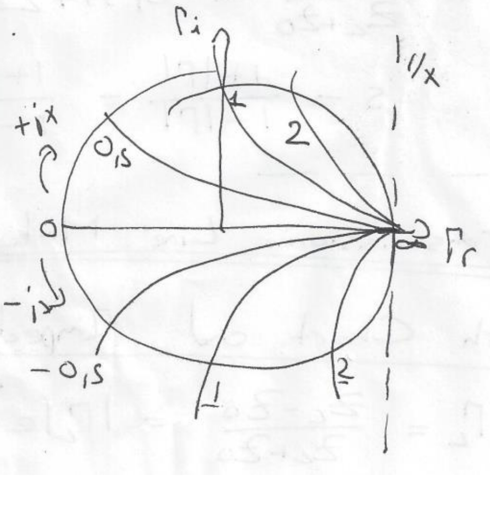
we can rearrange the above eq.s as;

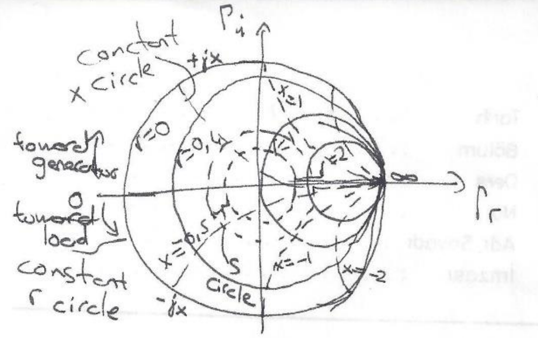
$$\left(\Gamma_r - \frac{r}{1+r}\right)^2 + \Gamma_i^2 = \left(\frac{1}{1+r}\right)^2$$

$$(\Gamma_r - 1)^2 + \left(\Gamma_i - \frac{1}{x}\right)^2 = \left(\frac{1}{x}\right)^2$$

These eq.s represents a family of circles, for the first eq., radius is $1/(1+r)$ and center is $\Gamma_r = r/(1+r)$, $\Gamma_i = 0$, for the second eq., $\Gamma_r = 1$ and $\Gamma_i = 1/x$ are the center coordinates and the radius is $1/x$.







The Smith chart also contains relative distance scales (in wavelength) along the circumference and a phase scale specifying the angle of the reflection coefficient.

When you locate a normalized z impedance on the chart, you can then find the normalized impedance of any other location along the line by using the relation:

$$z = \frac{1+\Gamma_\ell e^{-2\gamma d}}{1-\cancel{\beta}\Gamma_\ell e^{-2\gamma \ell}} \quad \text{where } \Gamma_\ell e^{-2\gamma d} = |\Gamma_\ell| e^{-2\alpha d} e^{j(\theta_\ell - 2\beta d)}$$

You can also use the Smith chart to determine normalized admittance. Since $Y_0 = 1/Z_0 = G_0 + jB_0$ and $Y = 1/Z = G + jB$, the normalized admittance is

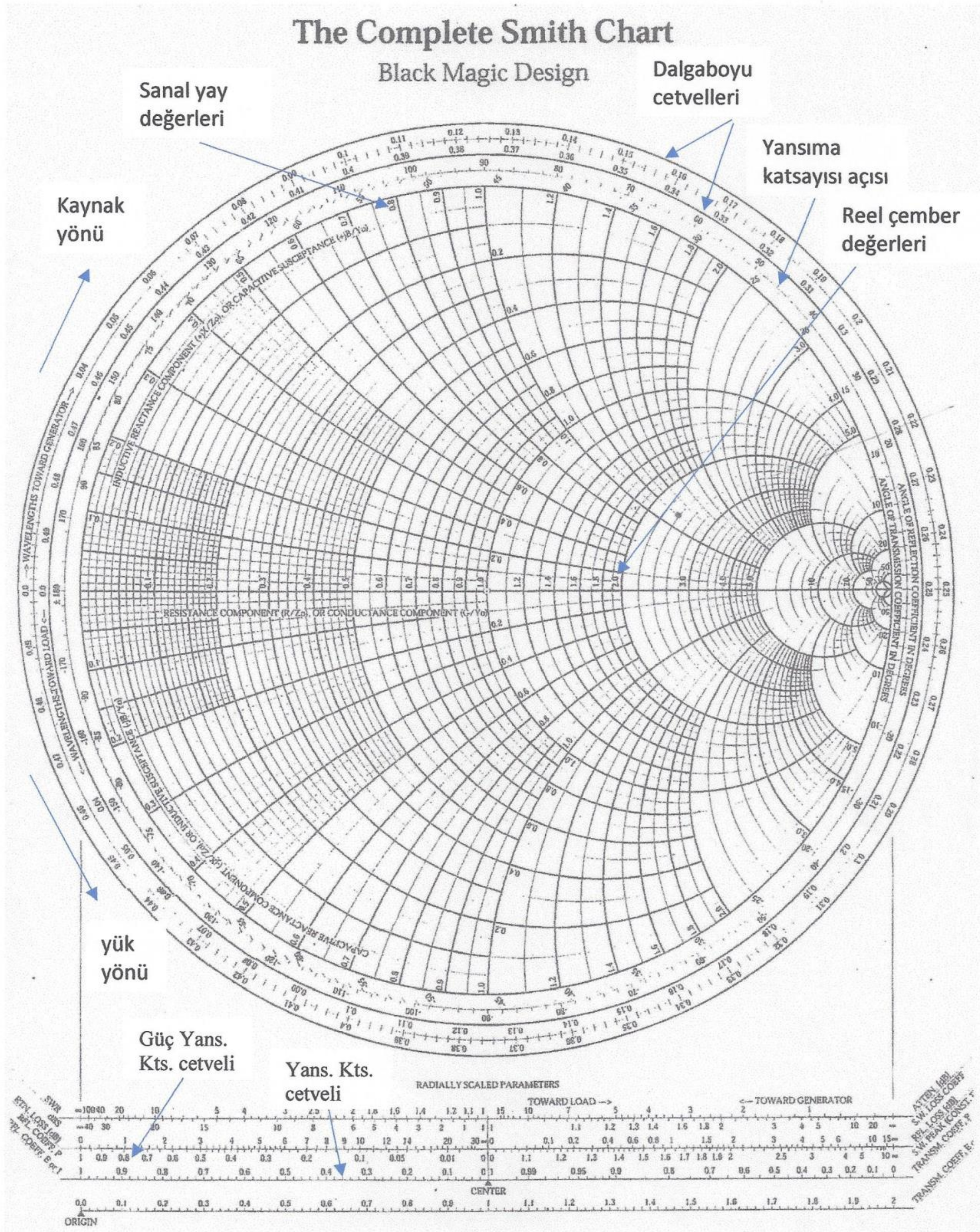
$$y = \frac{Y}{Y_0} = \frac{Z_0}{Z} = \frac{1}{z} = g + jb$$

Note that Γ is the radial coordinate and that the circles concentric with the center of the unit circle are circles of constant reflection coefficient. Since SWR is determined only by the magnitude of the Γ, these circles are also contours of constant standing-wave ratio. Since the SWR is never less than one, the scale for the SWR varies from 1 to ∞ on the real axis. Note also that the distances are given in wavelengths toward both the generator and the load, so that we can easily determine in which direction to advance as position on the line changes.

We can summarize the Smith chart properties as follows:

1. The constant r and x loci form two orthogonal circles families on the chart.
2. The constant r and x circles all pass through the point ($\Gamma_r = 1, \Gamma_i = 0$).
3. The upper half of the diagram represents $+jx$
4. The lower " " " " $-jx$
5. For admittance, r circles become g circles, and x circles become b circles.
6. The distance around the Smith chart once is $\lambda/2$.
7. At a point of $z_{min} = 1/s$, there is a V_{min} on the line.
8. " " " " $z_{max} = s$, " " " V_{max} " " "
9. The horizontal radius to the right of the chart's center corresponds to V_{max}, I_{min}, z_{max} and s
10. " " " " " left " " " " " " V_{min}, I_{max}, z_{min} and $1/s$
11. The corresponding quantities in the admittance chart are 180° out of phase with those in the impedance chart.
12. The normalized impedance (or admittance) is repeated for every one-half wavelength of distance.

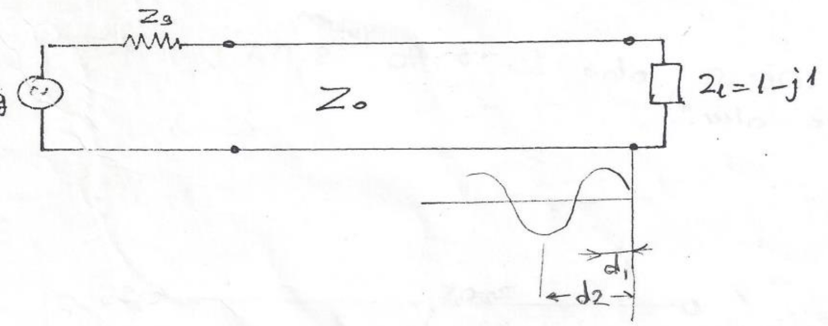
You can use the standing-wave pattern (or SWR) on the chart to calculate $|\Gamma|$, reflected and transmitted power and the load impedance. Typical values are shown at the bottom of the complete Smith chart.


The Complete Smith Chart
Black Magic Design
Sanal yay değerleri
Dalgaboyu cetvelleri
Yansıma katsayısı açısı
Reel çember değerleri
Kaynak yönü
yük yönü
Güç Yans. Kts. cetveli
Yans. Kts. cetveli
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE (-jB/Yo)
WAVELENGTHS TOWARD GENERATOR →
← WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
RADIALLY SCALED PARAMETERS
TOWARD LOAD →
← TOWARD GENERATOR
CENTER
ORIGIN

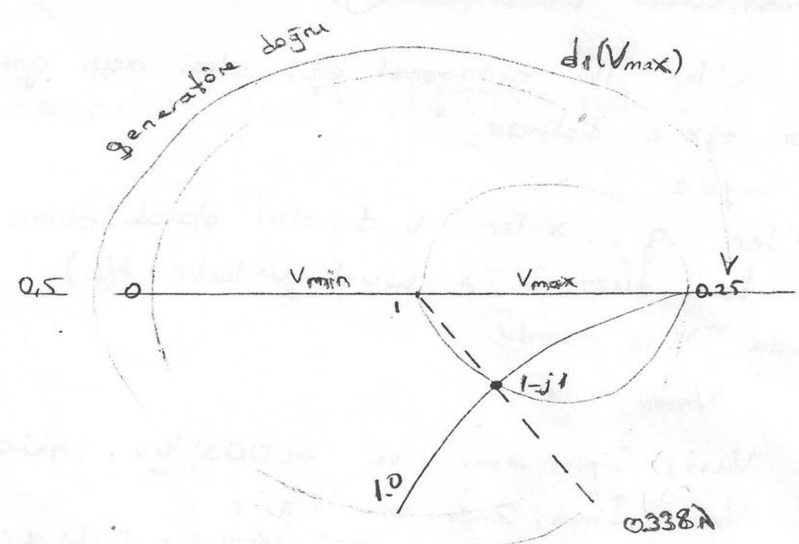
① Örnek:

Normalize yük emp.ı $z_\ell = 1 - j1$, çalışma dalgaboyu $\lambda = 5$ cm

) a) V_{max} ~~ın~~ ilk 'in b) V_{min} ~~in~~ ilk yükten ne kadar uzaktaki ~~ilk değerler~~ oluşacağını bul c) $S = ?$.



a) z_ℓ abakta işaretlenir.



2. merkez ile yük birleştirilirse 0.338λ okunur.
3. 0.338λ'dan kaynağa doğru ger. max. a kadar dönülür.

$$d_1(V_{max}) = (0.25 + 0.162)\lambda = 2.06 \text{ cm}.$$

b) 0.338 λ'dan ger. min.a kadar dönülür.

$$d_2(V_{min}) = (0.5 - 0.338)\lambda = 0.81 \text{ cm}.$$

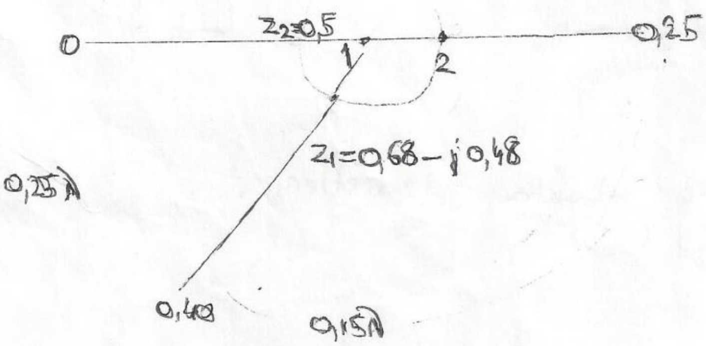
c) DDO'yu bulmak için merkezi (1.0) olan ve yükten geçen daire çizilir. DDO dairesi ile reel exenin sağ tarafını kesen noktadan $DDO = S = 2.6$ okunur.

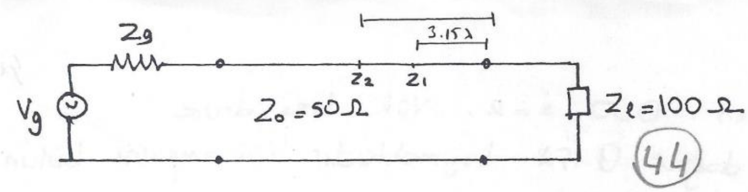
Örnek:

$Z_0 = 50\,\Omega$ $\quad Z_\ell = 100\,\Omega$ olan bir hatta yükten 3.15λ ve 4.75λ uzaklıkta emp. ne olur?

$$z_\ell = \frac{Z_\ell}{Z_0} = 2$$

işaretlenir. DDO dairesi çizilir





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3.15λ ve 4.75λ sırasıyla 0.15λ ve 0.25λ'ya karşı gelir. 0.15λ koy. doğru dönülürse 0.40'a gelinir.

$z_1 = 0.68 - 0.48j$

0.25λ ise 0.50'ye karşı gelir.

$z_2 = 0.5$ (min direnç)

$Z_1 = 50 \cdot z_1 = 34 - j\,24\,\Omega$

$Z_2 = 50\, z_2 = 25\,\Omega$

Çeyrek dalga transformatör bağıntısından

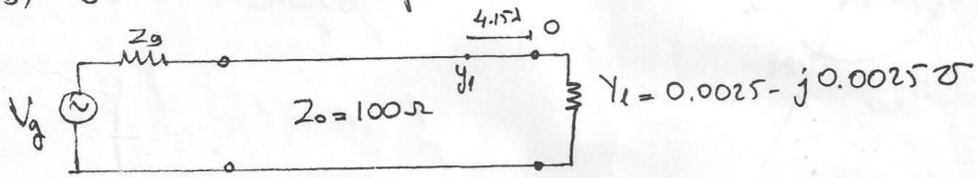
$$Z_0 = \sqrt{Z_2 \cdot Z_\ell} \;\longrightarrow\; Z_2 = \frac{Z_0^2}{Z_\ell} = \frac{2500}{100} = 25\,\Omega$$

Örnek:

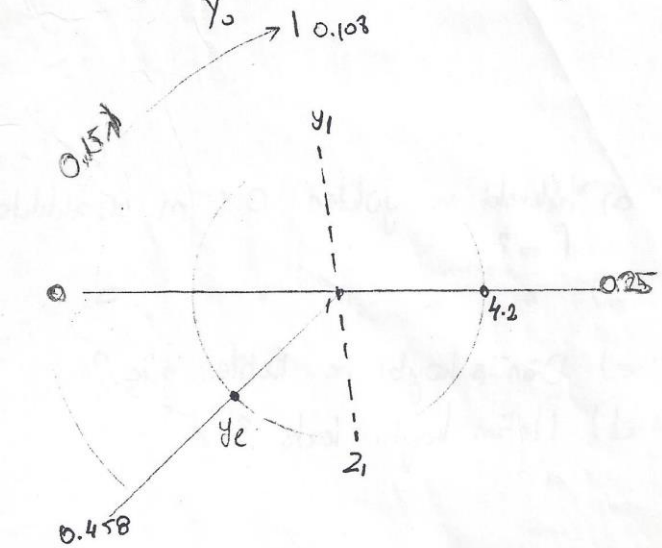
$Z_0 = 100\,\Omega \quad Y_l = 0.0025 - j0025\ ℧$

a) Yükten 4.15λ uzakta DDO $s = ?$. ?

b) Bu noktadaki emp. nedir?.



a) $y_l = \dfrac{Y_l}{Y_0} = Y_l Z_0 = 0.25 - j\,0.25$



Abakta işaretlenir.

DDO dairesi işaretlenir.

$s = 4.2$ okunur.

b) 0.458'deki ye'den 4.15λ kay.a doğru ilerlenir.

0.108'de durulur.

$y_1 = 0.38 + j0.74$ bulunur.

180° dönmüş hali z_1'dir

$z_1 = 0.55 - j\,1.1$

$Z_1 = Z_0 . z_1 = 550 - j110\,\Omega$