High-Speed Electronics in Practice

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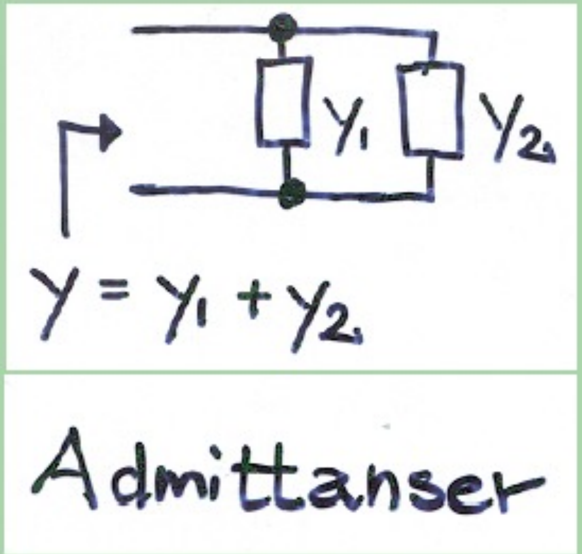
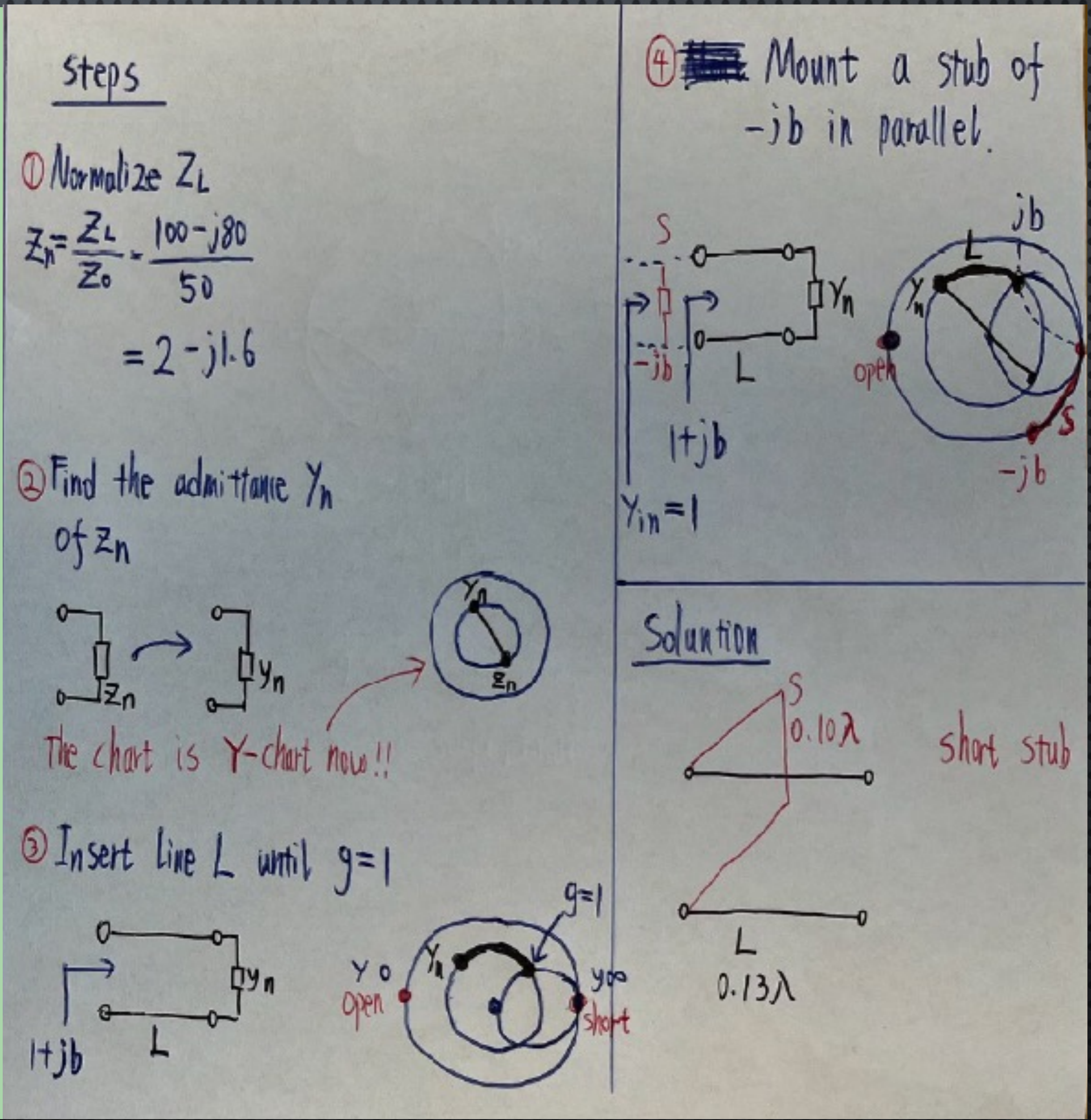
MM13. Cable Models and Power Ratio

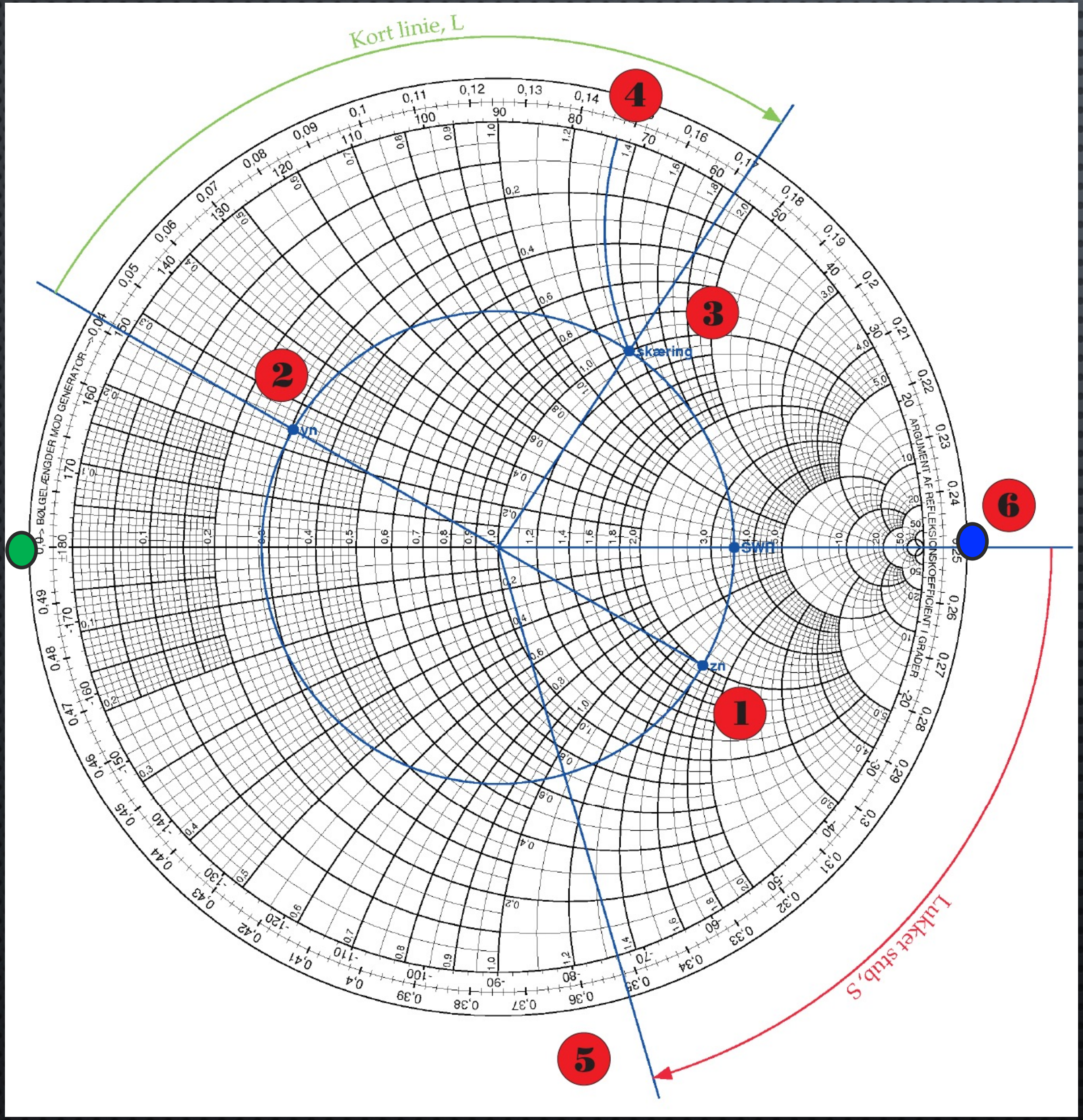
Recall



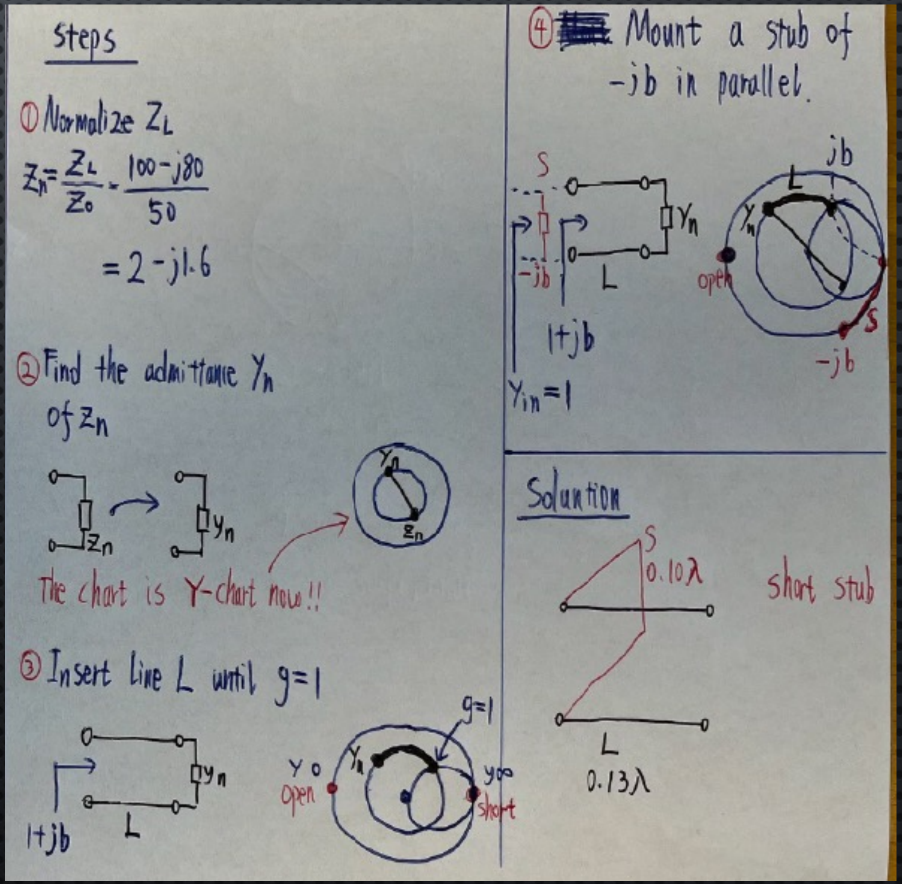
Single Stub Impedance Transformer



Recall

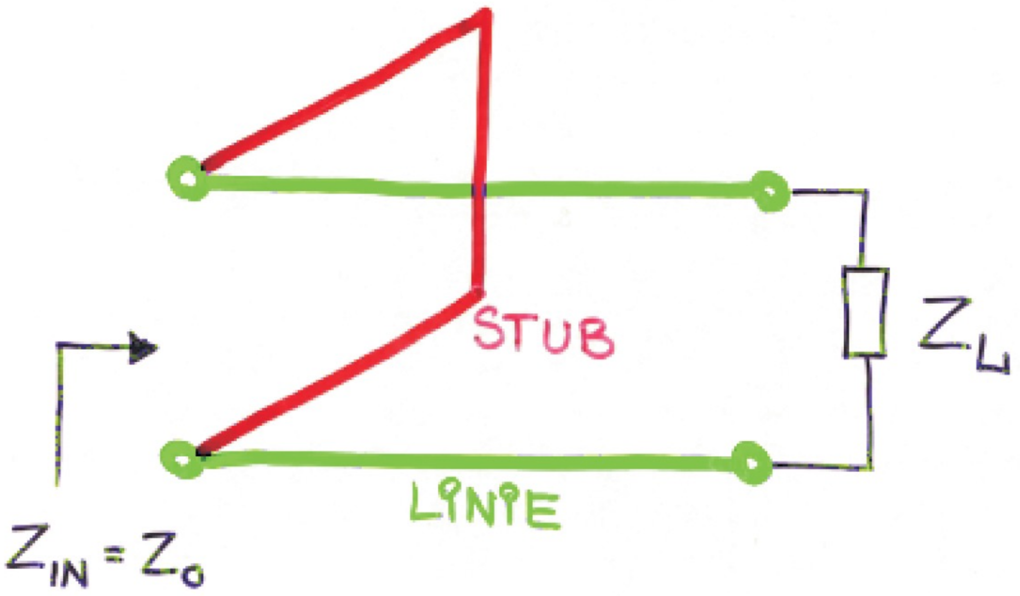


1. **Rotate clockwise (from load to source direction).**
2. **It is admittance now. If it is short-circuit stub, start from blue point. If it is open-circuit stub, start from green point.**



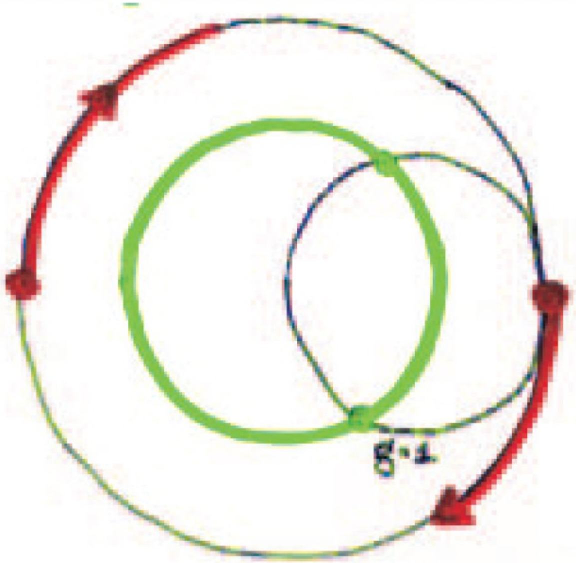
Recall

Single Stub Impedance Transformer



There are always 4 solutions:

1. **Short line, open-circuit stub**
2. **Short line, short-circuit stub**
3. **Long line, open-circuit stub**
4. **Long line, short-circuit stub**



Recall

CIRKLER I SMITHKORTET

Smith chart with other information

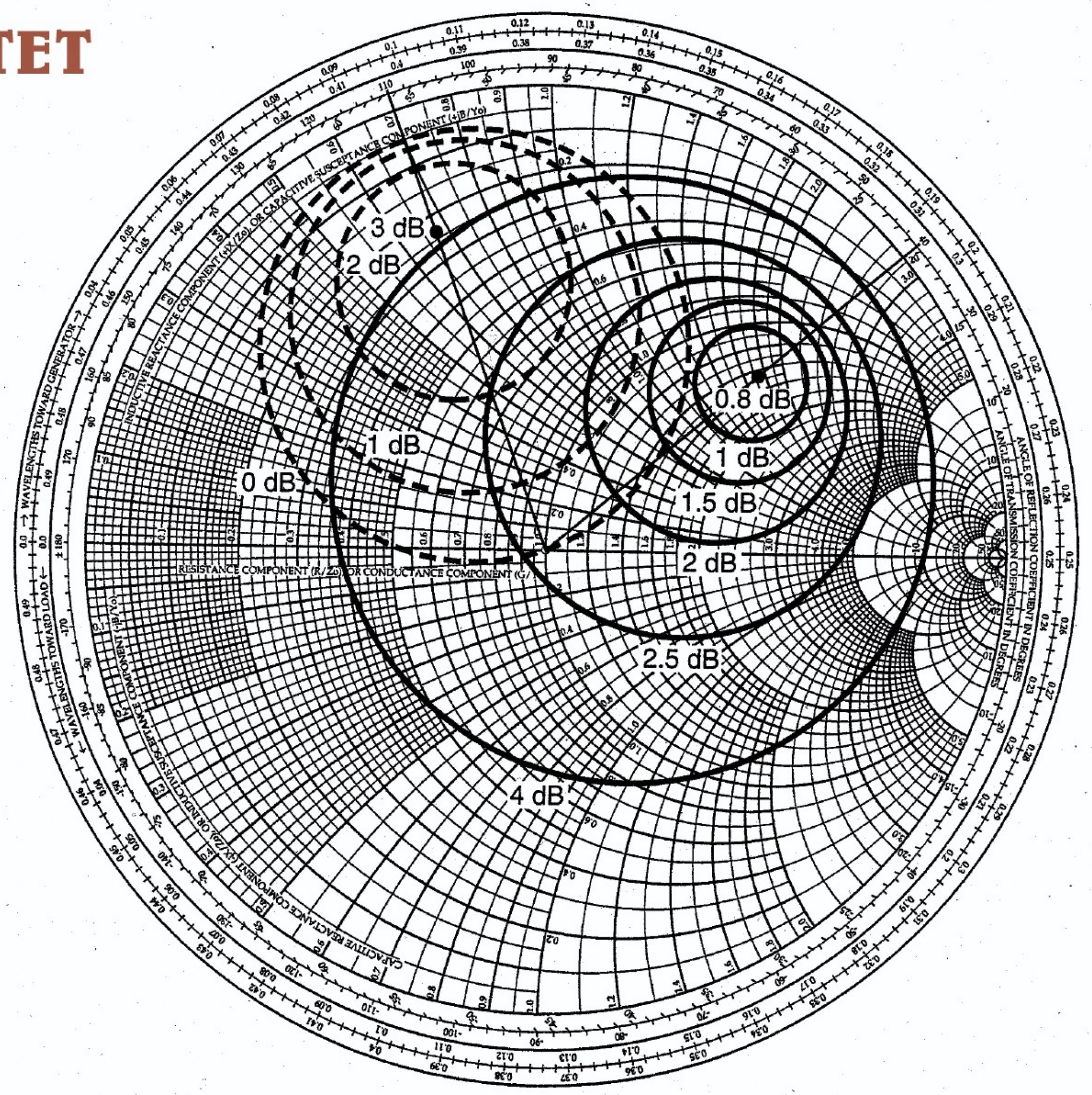


Figure 4.3.3 Noise figure circles (solid curves) and G_s constant-gain circles (dashed curves). The transistor is a GaAs FET with $V_{DS} = 4$ V, $I_{DS} = 12$ mA, and $f = 6$ GHz.

Gonzales, G.:
Microwave Transistor Amplifiers, 2. ed.
Prentice Hall, 1997
ISBN 0-13-254335-4
Fig. 4.3.3 page 302

CABLE MODELS AND POWER RATIO

Targets:

1. Read “Grundlmggende Transmissionsledningsteori” (Page 38-44, 46-48, 93-100) (before or after the lecture)

2. Be able to calculate with cable model and power calculation in KSN (lecture)

3. Finish the exercise (after the lecture)

Transmissionline Cable Models for Calculations

1. Calculate between the primary and secondary cable constant

$$L, C, R, G \longleftrightarrow Z_0, \gamma$$

2. Calculate K_L from Z_O and Z_L

3. Calculate between the impedance and reflection coefficient.

$$K(x) \longleftrightarrow Z(x)$$

4. Calculate voltage and current

$$V(x),\ I(x),\ V^{+}(x),\ V^{-}(x),\ I^{+}(x),\ I^{-}(x)$$

5. Calculate transmission and loss power

$$P_{TRANS}(x),\ P_{TAB}(x)$$

Blackboard (1)(2)

Calculations with Lossy Cables

Neper:

$$A_{Np} \triangleq \ln A \quad [Np]$$

where $A = \frac{V_1}{V_2}$ or $\frac{I_1}{I_2}$ $[\cdot]$

$$1\ Np = 20 \log e\ dB = 8.686\ dB$$

$(e \approx 2.72)$

EXAMPLE:

22 mm coax med helixisolation	37 dB/km @ 200MHz
RG-8/U	88 dB/km @ 200MHz
	70 dB/km @ 100 MHz
	4 dB/km @ 1 MHz

88 dB/km = 10,1 Np/km = 0,0101 Np/m

4 dB/km = 0,46 Np/km = 0,0005 Np/m

Calculations with Lossy Cables

SMITH CHART WITH LOSSY CABLE

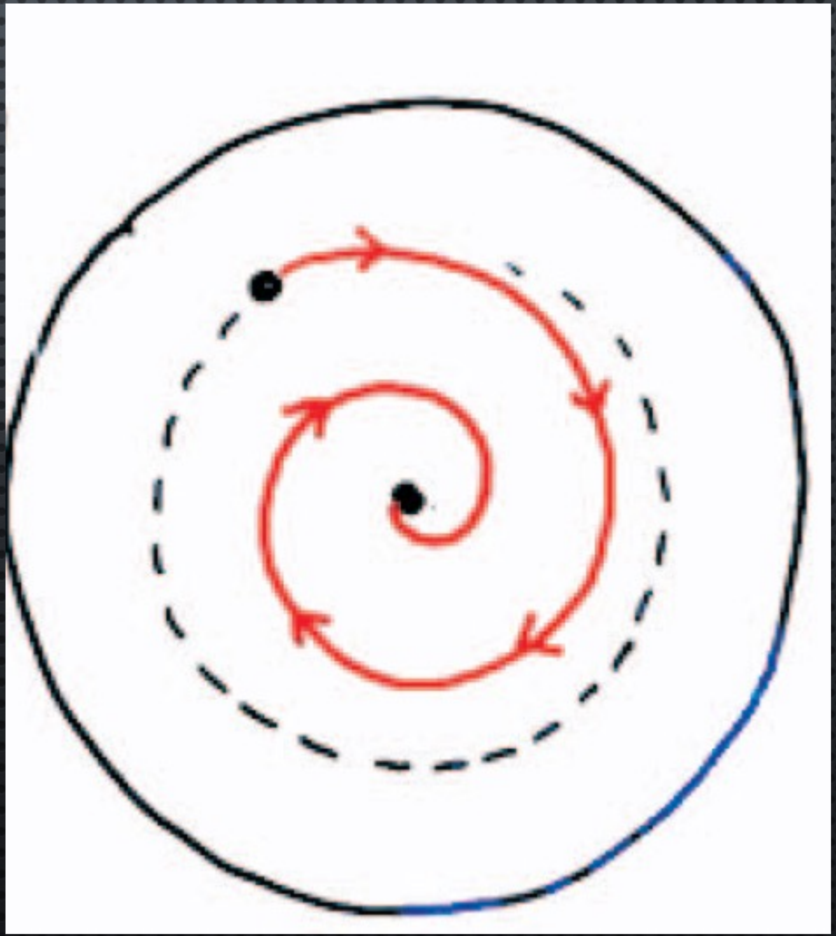
$$k(x) = \frac{V^-(x)}{V^+(x)} = \frac{V^-}{V^+} \cdot e^{2\gamma x}$$

$$= k_L \cdot e^{2\alpha x} \cdot e^{2j\beta x} \; [\cdot]$$

For $x = -\infty$ $(l = \infty)$, we have

$$k(-l) \to 0$$

$$Z(-l) \to Z_0$$



Power Calculations in KSN with Lossy Cables

Blackboard (3)

Instantaneous power

$$P_{ØJEBLIK}(t) \triangleq V(t)\cdot I(t)$$

$$= V\cos(\omega t+\varphi)\cdot I\cos(\omega t+\theta)$$

$$= \tfrac{1}{2}\cdot(VI\cos(\varphi-\theta)) + \tfrac{1}{2}(VI\cos(2\omega t+\varphi+\theta))$$

Average power

$$P_{MIDDEL} \triangleq \frac{1}{T}\int_{t_0}^{t_0+T} P_{ØJEBLIK}(t)\,dt = \tfrac{1}{2}VI\cos(\varphi-\theta)$$

Average power

$$P_{MIDDEL} \triangleq \frac{1}{T}\int_{t_0}^{t_0+T} P_{ØJEBLIK}(t)\,dt = \tfrac{1}{2}VI\cos(\varphi-\theta)$$

Power in KSN

KSN

$$P_{MIDDEL} = \tfrac{1}{2}\cdot \mathrm{Re}\left[V\cdot I^*\right]$$

$$= \tfrac{1}{2}\cdot \mathrm{Re}\left[Ve^{j\varphi}\cdot I e^{-j\theta}\right]$$

$$= \tfrac{1}{2}\cdot \mathrm{Re}\left[VI e^{j(\varphi-\theta)}\right]$$

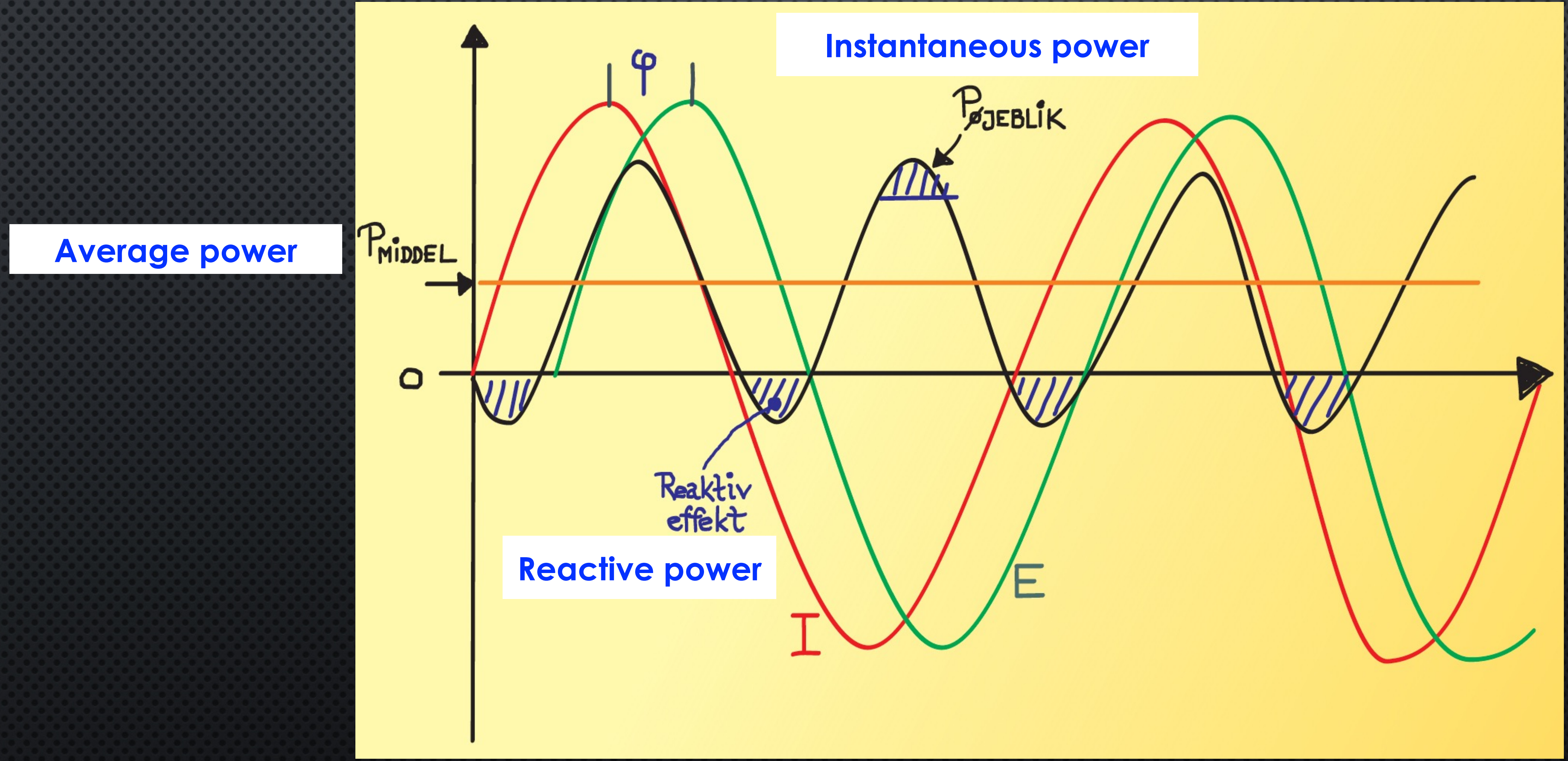
$$= \tfrac{1}{2}VI\cdot\cos(\varphi-\theta)$$

SAMME

The power in KSN is actually the power in time average.

Power Calculations in KSN with Lossy Cables

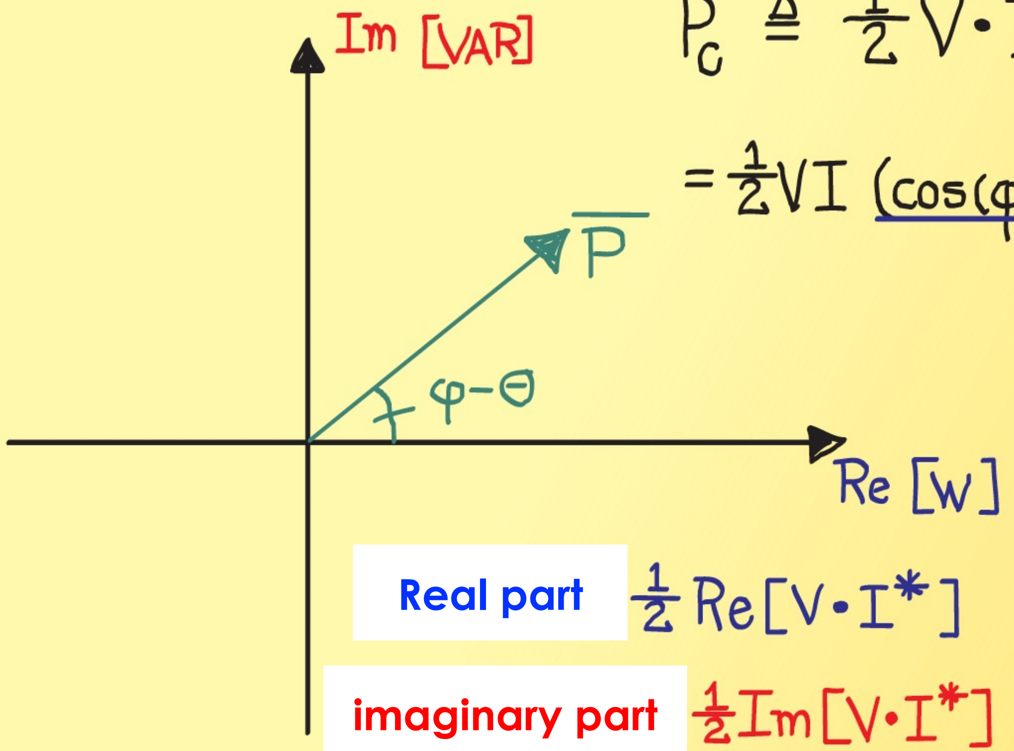
Instantaneous power V.S. Average power



Power Calculations in KSN with Lossy Cables

Instantaneous power V.S. Average power

Complex power



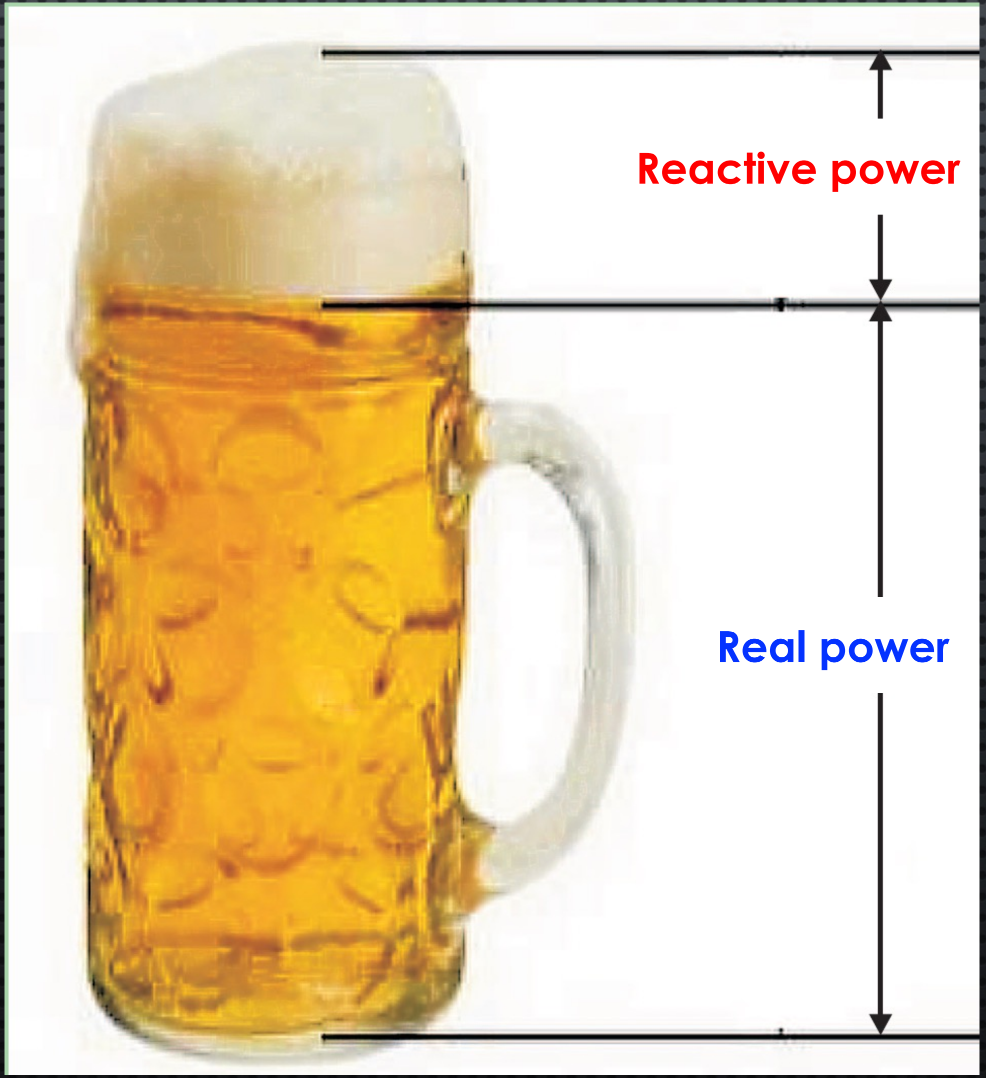
$$P_c \triangleq \frac{1}{2} V \cdot I^* \quad [VA]$$

$$= \frac{1}{2} VI \left(\underline{\cos(\varphi-\theta)} + j\,\underline{\sin(\varphi-\theta)} \right)$$

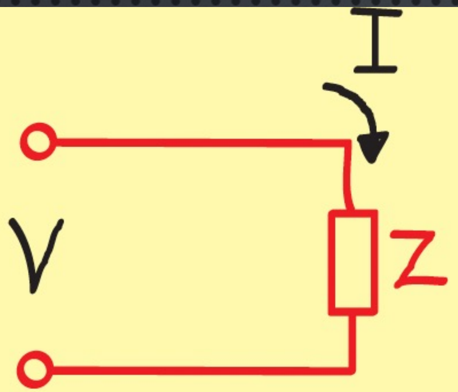
Real part	$\frac{1}{2} Re[V \cdot I^*]$	Real power	[W]
imaginary part	$\frac{1}{2} Im[V \cdot I^*]$	Reactive power	[VAR]

Power Calculations in KSN with Lossy Cables

Instantaneous power V.S. Average power



Power in an Impedance Load (KSN)



$$I = \frac{V}{Z}$$

$$P_{MID.} = \frac{1}{2}\mathrm{Re}\left[V\cdot I^*\right] = \frac{1}{2}\mathrm{Re}\left[V\cdot V^*\frac{1}{Z^*}\right]$$

$$= \frac{1}{2}\mathrm{Re}\left[|V|^2\cdot\frac{Z}{|Z|^2}\right]$$

$$= \frac{1}{2}\left|\frac{V}{Z}\right|^2\cdot\mathrm{Re}[Z] \qquad = \frac{1}{2}|I|^2\cdot\mathrm{Re}[Z]$$

Rules for conjugate calculations

$$Z\cdot Z^* = |Z|^2 = |Z^2| \qquad \frac{|Z_1|}{|Z_2|} = \left|\frac{Z_1}{Z_2}\right|$$

$$\frac{1}{Z^*} = \frac{Z}{|Z|^2}$$

$$\left(\frac{Z_1}{Z_2}\right)^* = \frac{Z_1^*}{Z_2^*} \qquad Z = a+jb$$

$$Z^* = a-jb$$

$$(Z_1+Z_2)^* = Z_1^* + Z_2^* \qquad |Z| = \sqrt{a^2+b^2}$$

$$Z = a+jb \qquad M\angle\varphi = M(\cos\varphi + j\sin\varphi)$$

$$Z^* = a-jb \qquad M\angle{-\varphi} = M(\cos{-\varphi} + j\sin{-\varphi})$$

$$= M(\cos\varphi - j\sin\varphi)$$

$$|Z| = M = \sqrt{a^2+b^2}$$

$$\angle Z = \varphi = \mathrm{arctg}\,\frac{b}{a}$$

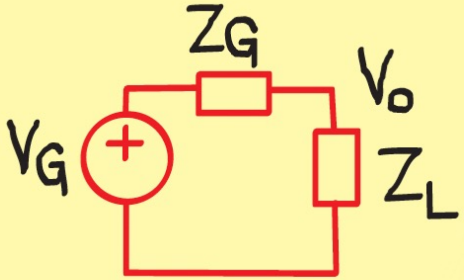
$$Z\cdot Z^* = a^2+b^2 = M^2 = |Z|^2 = |Z^2|$$

$$Z = \frac{|Z|^2}{Z^*}$$

Power Transmission (KSN)

Power calculation (KSN)

$$P = \mathrm{Re}\left[V \cdot I^*\right] \frac{1}{2} \qquad [W]$$



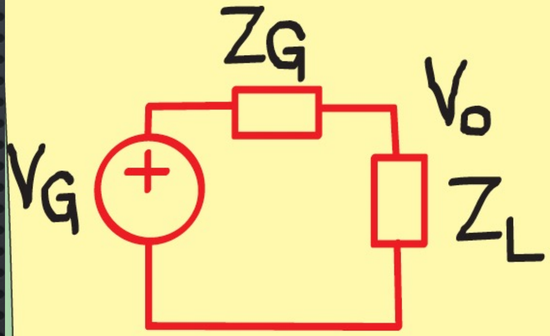
$$P_{Z_L} = \mathrm{Re}\left[V \cdot I^*\right] \frac{1}{2}$$

$$= \mathrm{Re}\left[V_G \cdot \frac{Z_L}{Z_G + Z_L} \cdot V_G^* \cdot \frac{1}{(Z_G + Z_L)^*}\right] \frac{1}{2}$$

$$= \frac{|V_G|^2}{|Z_G + Z_L|^2} \cdot \mathrm{Re}\left[Z_L\right] \frac{1}{2} [W]$$

Konjugeret tilpasning for $Z_L = Z_G^*$. Dette giver maximal effekt afsat i Z_L.

Power Transmission (KSN)



$$P_A = P_{ZL}\Big|_{Z_L = Z_G^*} = \frac{|V_G|^2}{|2\,Re[Z_G]|^2}\cdot Re[Z_G]\,\frac{1}{2}$$

$$= \frac{|V_G|^2}{4\,Re[Z_G]}\,\frac{1}{2} \quad [W]$$

Eller:

$$P_A = \frac{|V_0|^2}{|Z_L|^2}\cdot Re[Z_L]\,\frac{1}{2}$$

$$= \frac{|V_0|^2}{|Z_G|^2}\cdot Re[Z_G]\,\frac{1}{2} \quad [W]$$

Konjugeret tilpasning for $Z_L = Z_G^*$. Dette giver maximal effekt afsat i Z_L.