High-Speed Electronics in Practice

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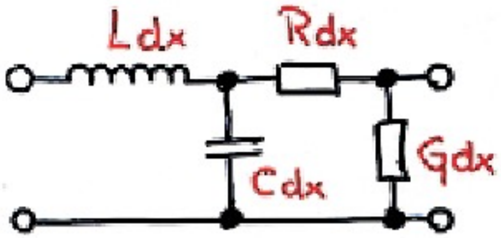
High-Speed Electronics in Practice

MM10. Solution for Harmonic Signals

Recall for MM7

General formula

Model for cable

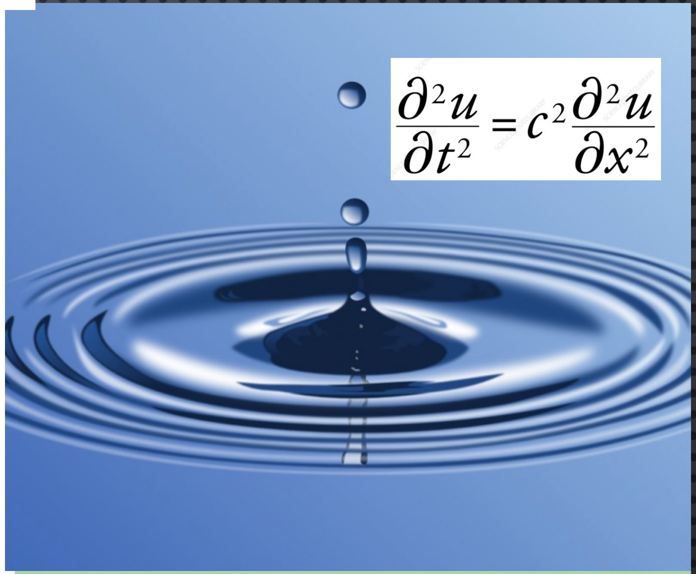


Telegraph equation

Lossless R=G=0

$$\frac{\partial V}{\partial x} = -L \cdot \frac{\partial I}{\partial t}$$

$$\frac{\partial I}{\partial x} = -C \cdot \frac{\partial V}{\partial t}$$



$$\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2}$$

Wave equation

Lossless R=G=0

$$\frac{\partial^2 V}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 V}{\partial t^2}$$

$$\frac{\partial^2 I}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 I}{\partial t^2}$$

Solutions

$$V = V^+\left(t - \frac{x}{v}\right) + V^-\left(t + \frac{x}{v}\right)$$

$$I = I^+\left(t - \frac{x}{v}\right) + I^-\left(t + \frac{x}{v}\right)$$

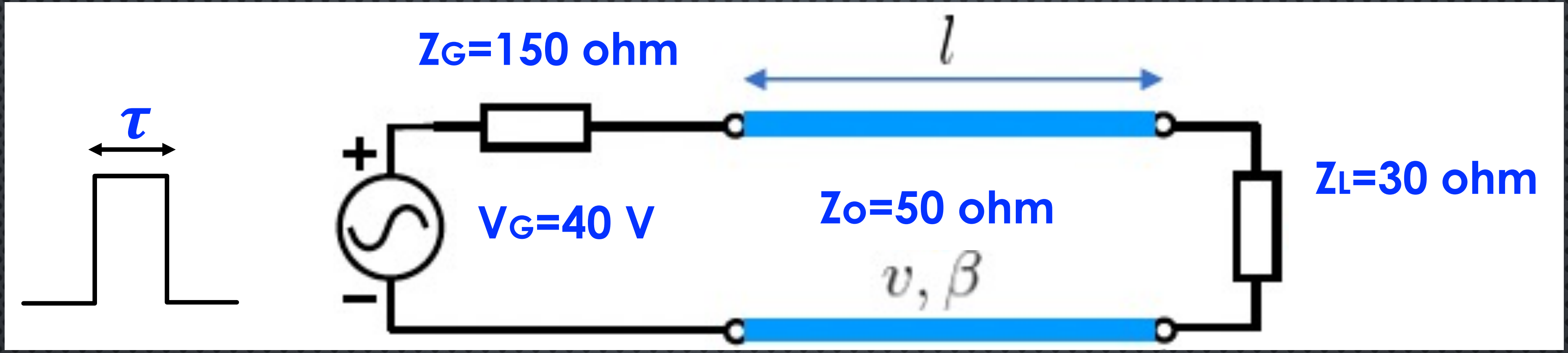
$$I = \frac{1}{Z_0}\left(V^+\left(t - \frac{x}{v}\right) - V^-\left(t + \frac{x}{v}\right)\right)$$

$$v = \frac{1}{\sqrt{LC}} \quad \left[\frac{m}{s}\right]$$

$$Z_0 = \sqrt{\frac{L}{C}} \quad [\Omega]$$

$$K_L = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{V^-}{V^+} = -\frac{I^-}{I^+}$$

Transient analysis (Time-Domain)



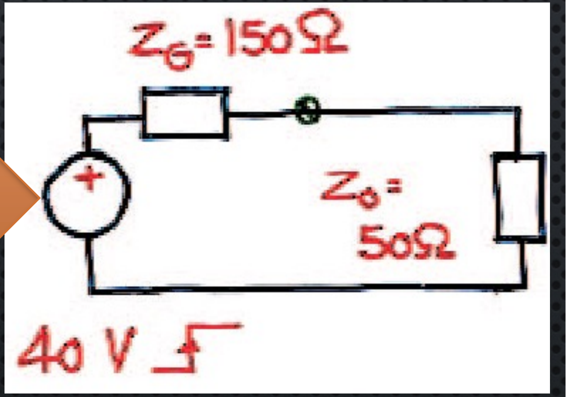
There are many ways to calculate it. We can also apply **transmission line theory** that gives more details.

Start:

$$V^+ = 40 \cdot \frac{50}{150+50} = \frac{2000}{200} = 10 \text{ V}$$

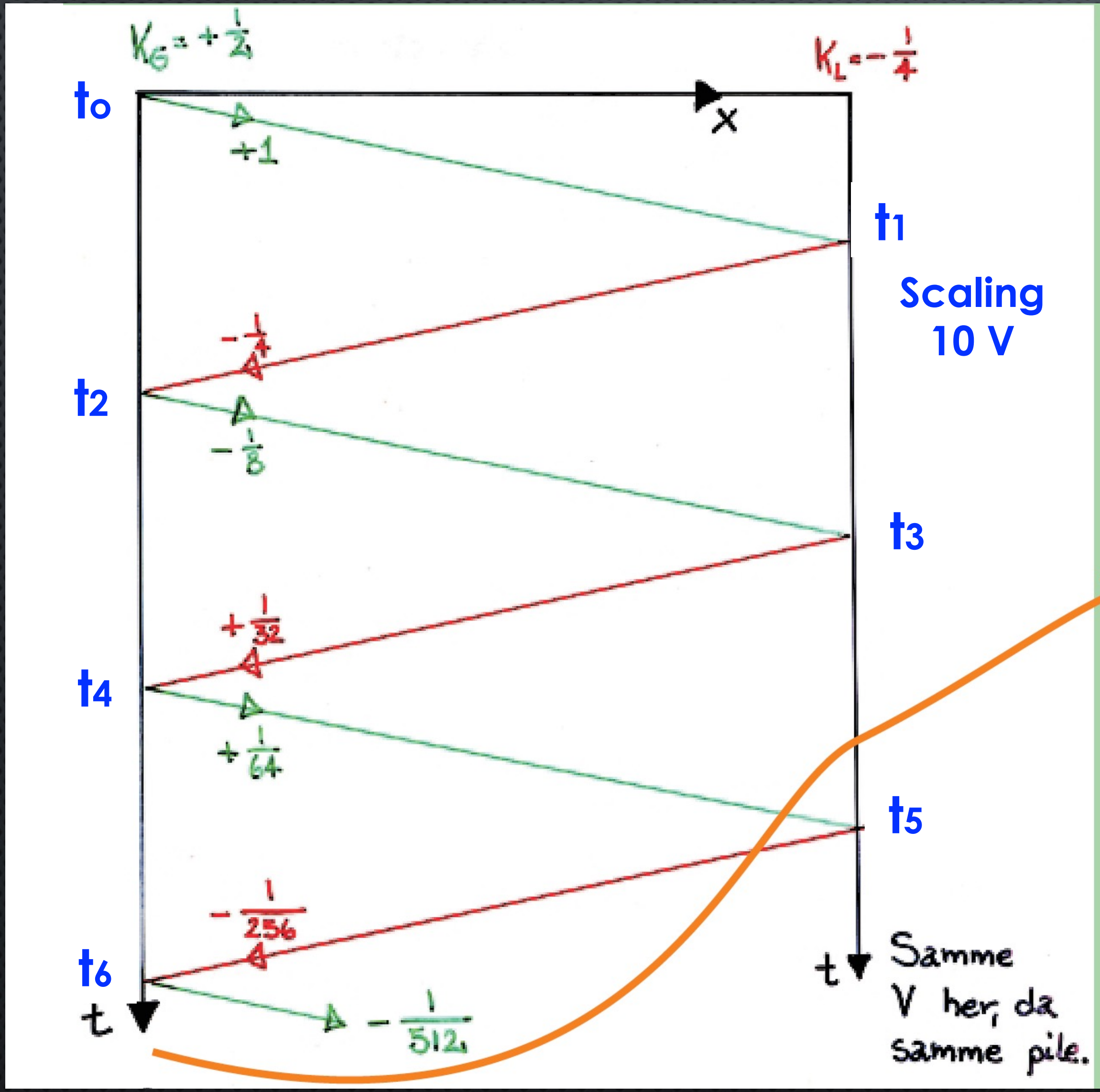
$$I^+ = 40 \cdot \frac{1}{150+50} = \frac{40}{200} = 0{,}2 \text{ A}$$

$$K_g = \frac{150-50}{150+50} = +\frac{1}{2} \qquad K_L = \frac{30-50}{30+50} = -\frac{1}{4}$$



Reflection Diagram

Reflection map

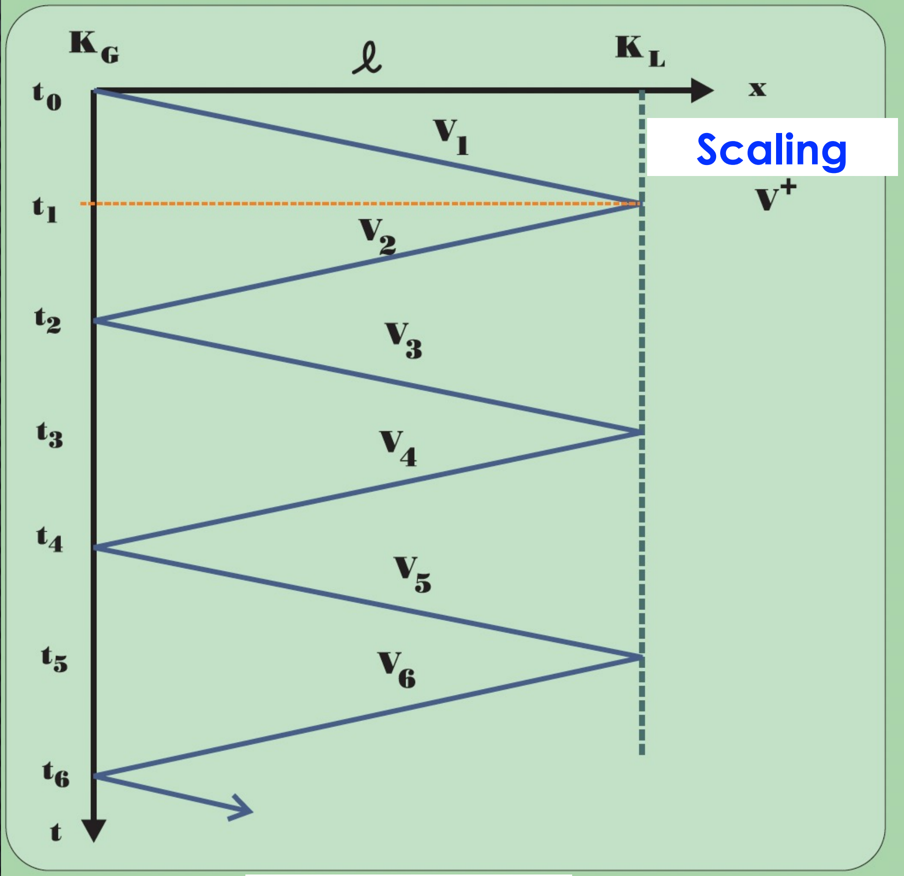


$$V_{TOTAL}\ @\ \otimes = 10\cdot$$

$$1 + \left(-\tfrac{1}{4}\right) + \tfrac{1}{2}\left(-\tfrac{1}{4}\right) + \tfrac{1}{2}\left(-\tfrac{1}{4}\right)^2 + \left(\tfrac{1}{2}\right)^2\left(-\tfrac{1}{4}\right)^2 + \ldots$$

$$= \left(\sum_{n=0}^{\infty}\left(-\tfrac{1}{8}\right)^n + \left(-\tfrac{1}{4}\right)\sum_{n=0}^{\infty}\left(-\tfrac{1}{8}\right)^n\right)\cdot 10 = \tfrac{3}{4}\cdot\tfrac{8}{9}\cdot 10 = \tfrac{20}{3}\ V$$

Reflection map



Diagram

Voltage calculation

$$V_1 = 1$$
$$V_2 = V_1 \cdot K_L$$
$$V_3 = V_2 \cdot K_G$$
$$V_4 = V_3 \cdot K_L$$
$$V_5 = V_4 \cdot K_G$$
$$V_6 = V_5 \cdot K_L$$

If it is current, it should apply:

$$K'_L = -K_L$$
$$K'_G = -K_G$$

Voltage

Time calculation

$$t_0 = 0$$
$$t_1 = t_0 + \Delta$$
$$t_2 = t_1 + \Delta$$
$$t_3 = t_2 + \Delta$$
$$t_4 = t_3 + \Delta$$
$$t_5 = t_4 + \Delta$$
$$t_6 = t_5 + \Delta$$

where

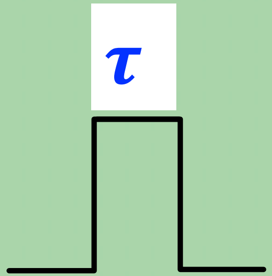
$$\Delta = \frac{\ell}{v} \quad [s]$$

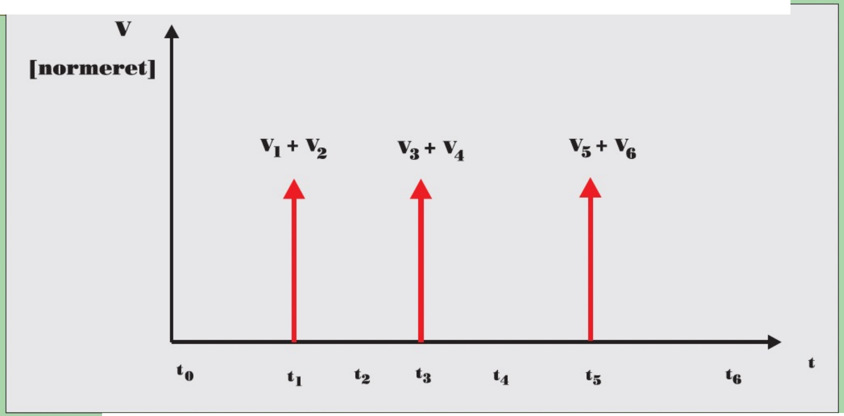
Time

It is smart and clear to calculate the voltage (current) and time in same tables.

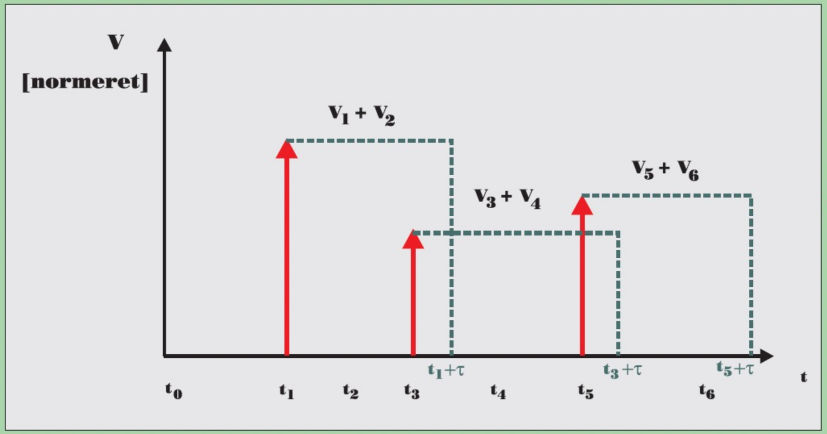
Stick diagram

Calculate the curve form with stick diagram

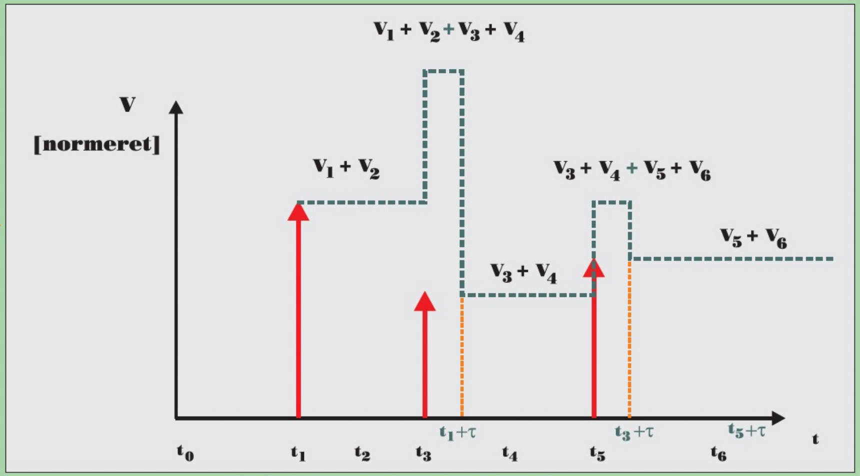




Make the wave leading edge with stick



Extend stick to full pulse width



Sum the impulse overlap part

SOLUTION FOR HARMONIC SIGNALS

Targets:

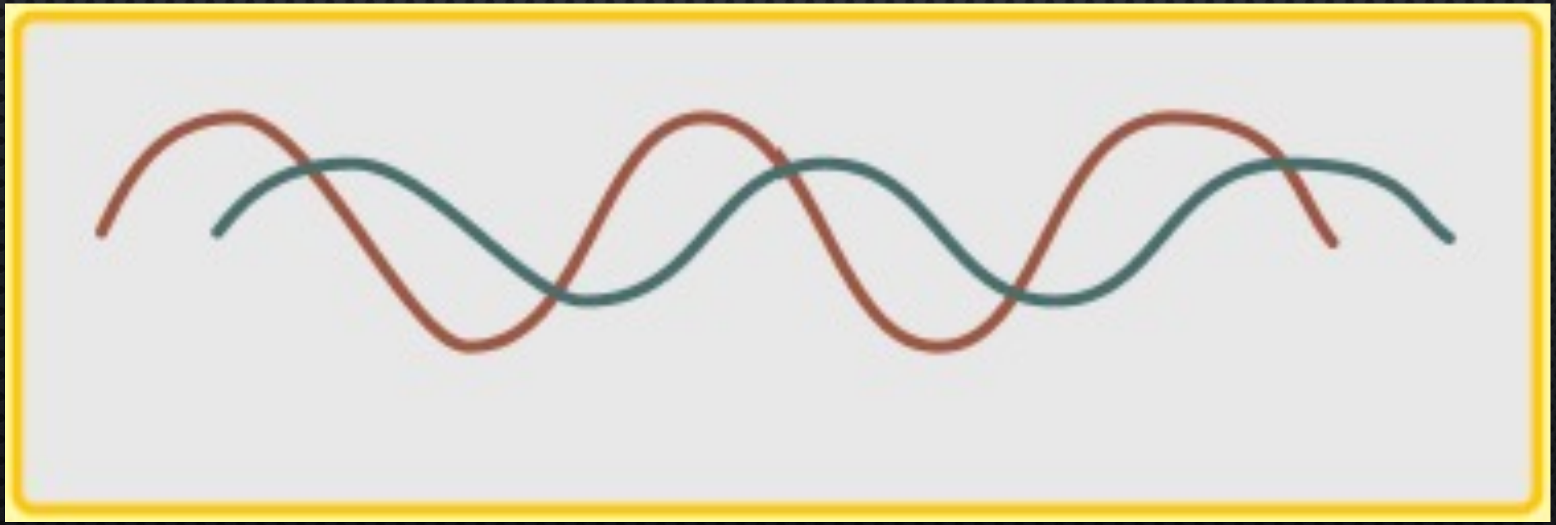
1. Read "Grundlmggende Transmissionsledningsteori" (Page 23-38, 105-108) (before or after the lecture)

2. Be able to calculate with general impedance and reflection coefficient solutions for sine signals (lecture)

3. Finish the exercise (after the lecture)

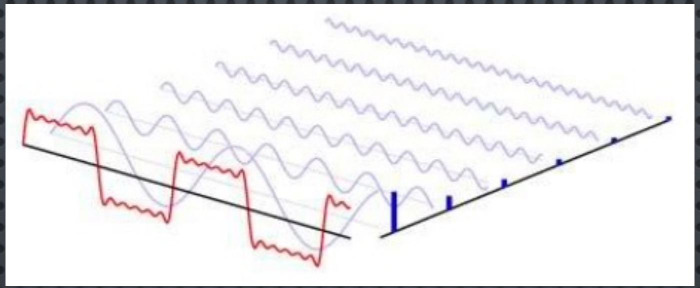
Sine Signals

- Signals of the form cos(wt) or sin(wt) are called sinusoidal signals or simply sine signals.
- A weighted sum of delayed sine signals with the same frequency is also a sine signal.



Sine Signals

- All signals can be expressed as a weighted sum of sine signals with different frequencies.



- For linear systems, the superposition principle applies.
- A sine signal that has passed through a linear system is also a sine signal.
- It is therefore interesting to investigate the behavior of systems when they are influenced by a sinusoidal signal.

Sine Signals in KSN

KSN

Kompleks Symbolsk Notation

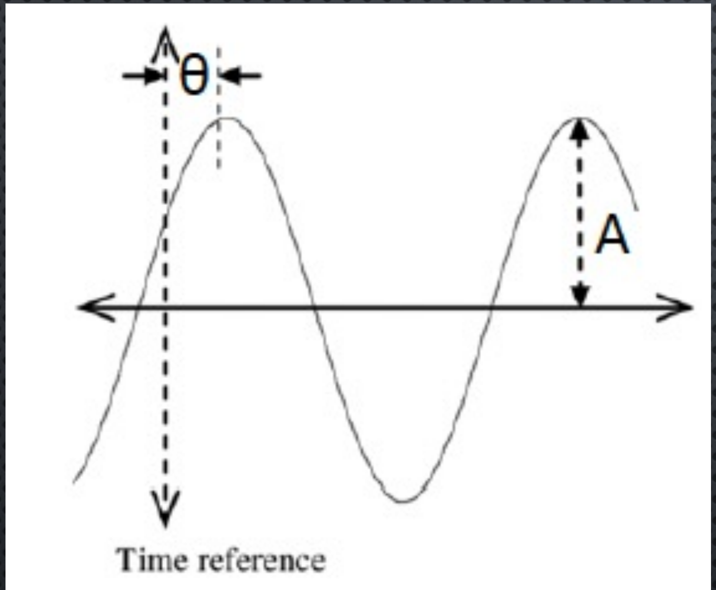
Also called “jw-method”.

KSN is used for sine and harmonic signals.

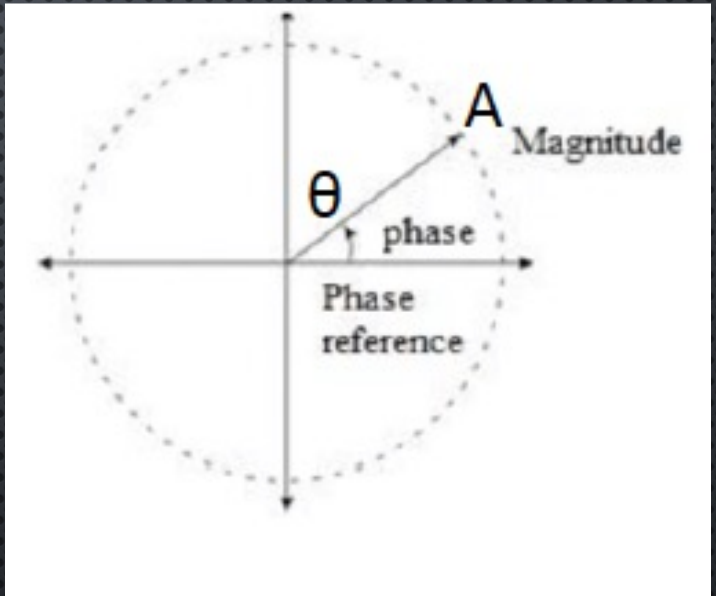
Sine Signals in KSN

Sine signals are mapped onto vectors in the complex number plane

$A\cos(\omega t + \theta)$ $\qquad$ $Ae^{j(\omega t+\theta)}$ $\qquad$ $A\angle\theta$



a) Sinusoidal waveform of a signal



b) Polar representation of the same signal

frekvens

$$\mathrm{Re}\left\{Ae^{j(\omega t+\theta)}\right\} = \mathrm{Re}\{A(\cos(\omega t+\theta) + j\sin(\omega t+\theta))\} = f(t) = A\cos(\omega t+\theta)$$

$$\omega = 2\pi f$$

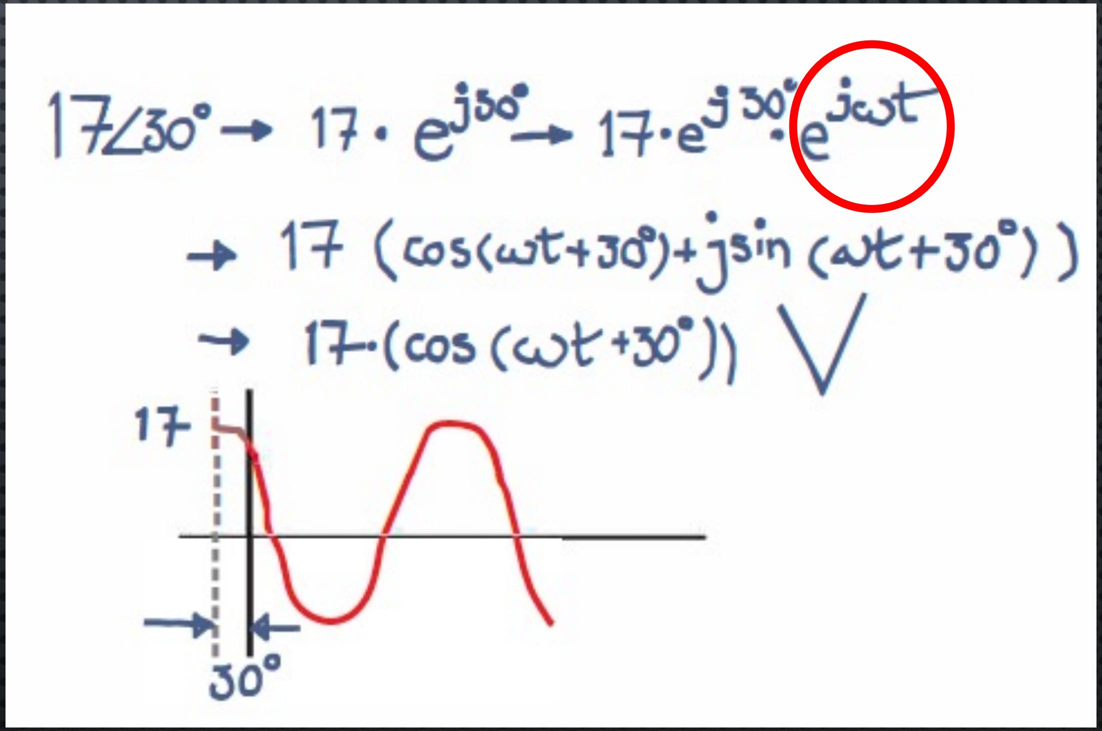
signal amplitude fase

$e^{jb} = \cos b + j \sin b$

Sine Signals in KSN

$$17\angle 30^\circ \ \mathrm{V}$$

- It cannot be seen from the notation what the frequency is. The phase reference is hidden.
- It is understood whether it is effective value or peak value that is indicated.
- All signals carried the same frequency.



Solution Types

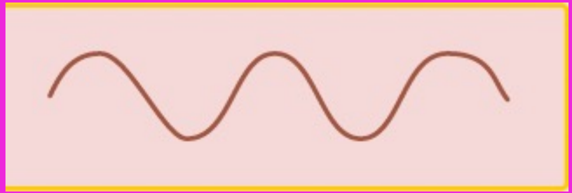
Statistic Solution

Statistic solution.
Solution for DC signal

Stationary Solution

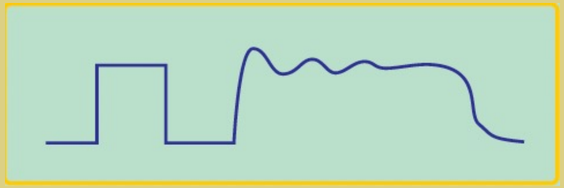
KSN

Stationary solution.
Also called harmonic solution.
Stationary AC mode is a dynamic mode where the signals in the system with the same series of values periodically to infinity.



Transient Solution

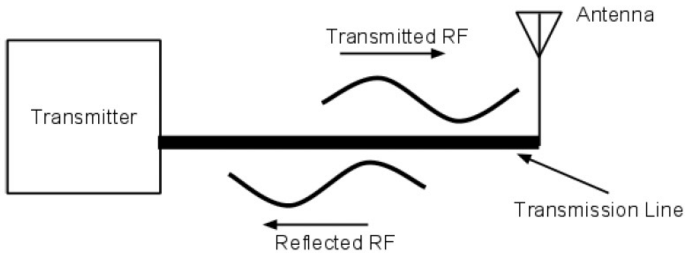
Transient solution.
Solution in time domain.
Typically, not sine signal.

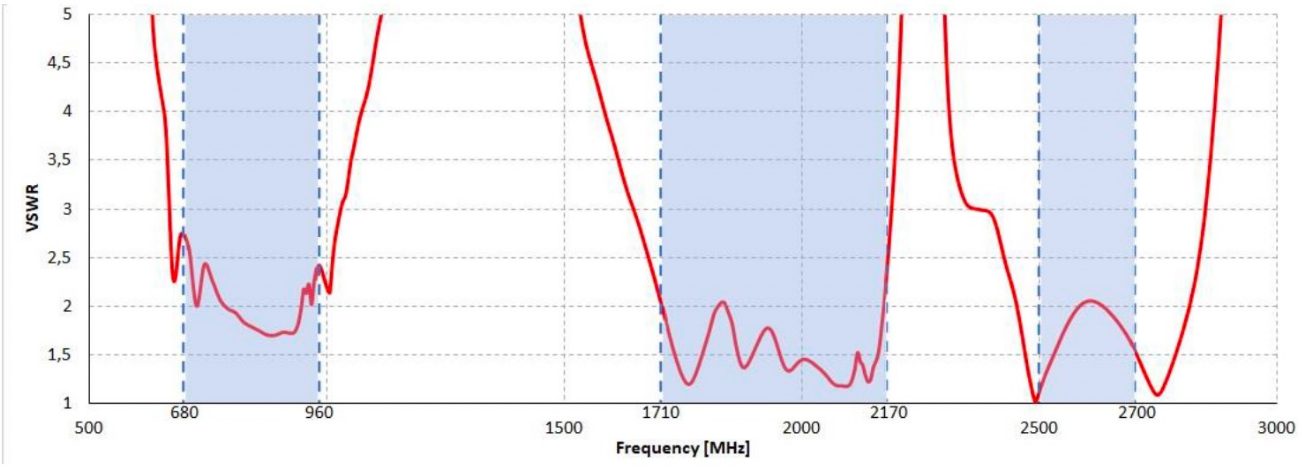


Blackboard (1)(2)

Generalized Impedance

Examples for PCB design





Blackboard(3)

Stubs for Load Impedance

Lukket stub

$Z = 0$

$y = \infty$

$$K_L = \frac{Z - Z_0}{Z + Z_0} = -1$$

ℓ	$Z(x)$
0	0
$\frac{\lambda}{8}$	jX (spole)
$\frac{\lambda}{4}$	∞
$\frac{3}{8}\lambda$	$-jX$ (kondensator)
$\frac{\lambda}{2}$	0

Quarter wavelength difference

$$Z(x) = Z_0 \cdot \frac{1 + K(x)}{1 - K(x)} \qquad [\Omega]$$

$$K(x) = K_L \cdot e^{j2\beta x} \qquad [\cdot]$$

$$K_L = \frac{Z_L - Z_0}{Z_L + Z_0} \qquad [\cdot]$$

Åben stub

$Z = \infty$

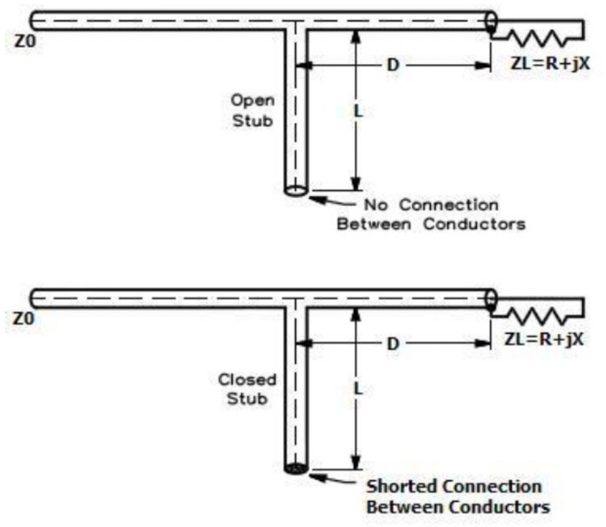
$y = 0$

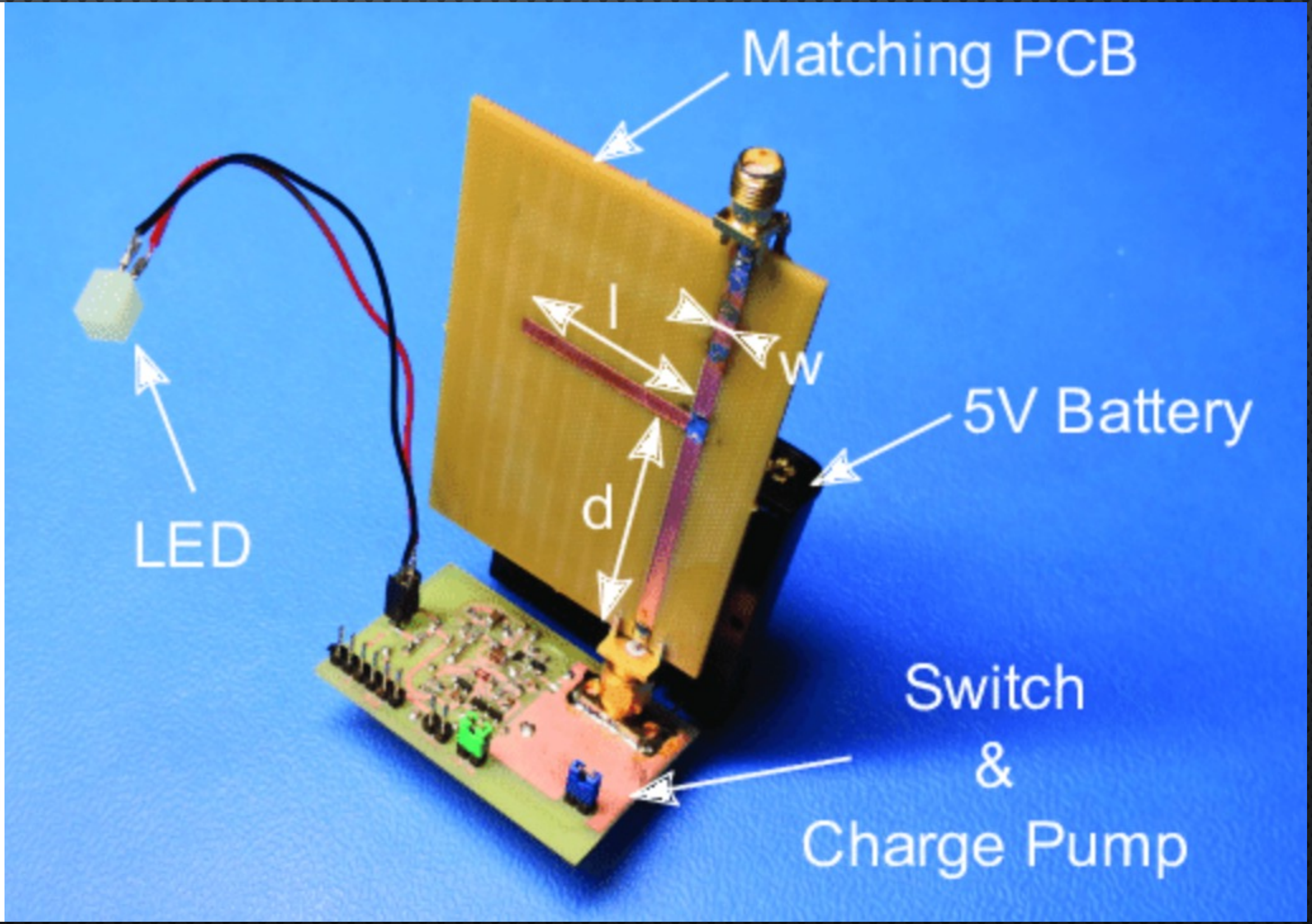
$$K_L = \frac{Z - Z_0}{Z + Z_0} = +1$$

ℓ	$Z(x)$
0	∞
$\frac{\lambda}{8}$	$-jX$ (kond.)
$\frac{\lambda}{4}$	0
$\frac{3}{8}\lambda$	jX (spole)
$\frac{\lambda}{2}$	∞

Stubs for Load Impedance

Examples for PCB design





Stubs for Load Impedance

Example 2 for PCB design