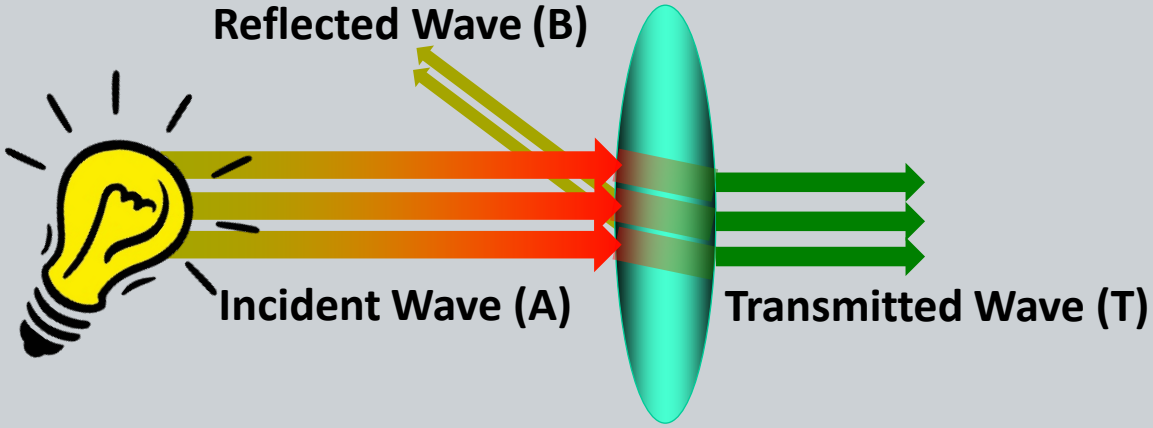
VNA Basics

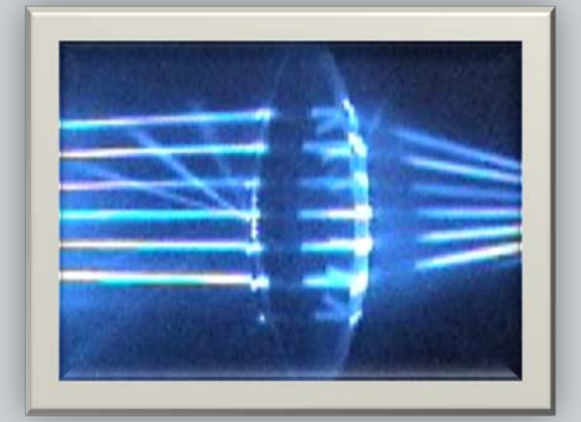
Germán Andrés Álvarez Botero

Laboratório de Radiofrequência

UNIVERSIDADE FEDERAL
DE SANTA CATARINA

S-parameters

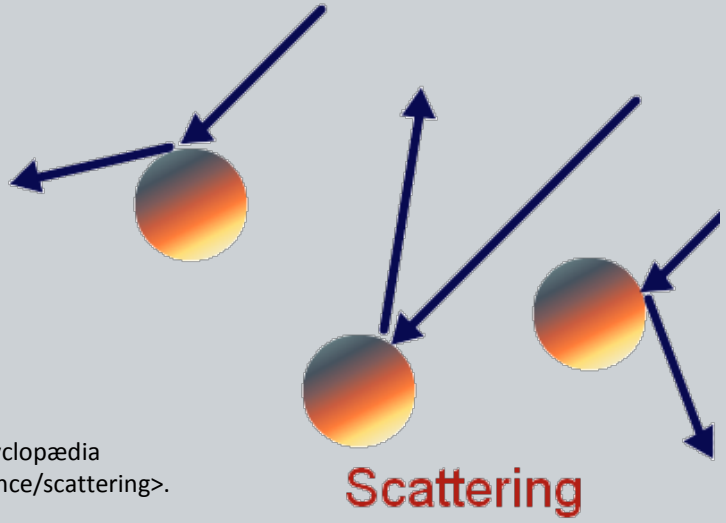




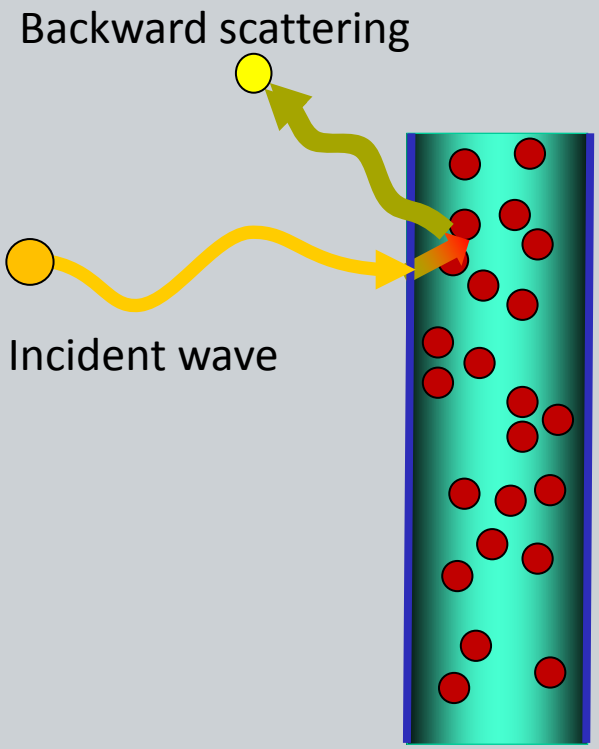
S-Parameters

Scattering, in physics, a change in the direction of motion of a particle because of a collision with another particle.

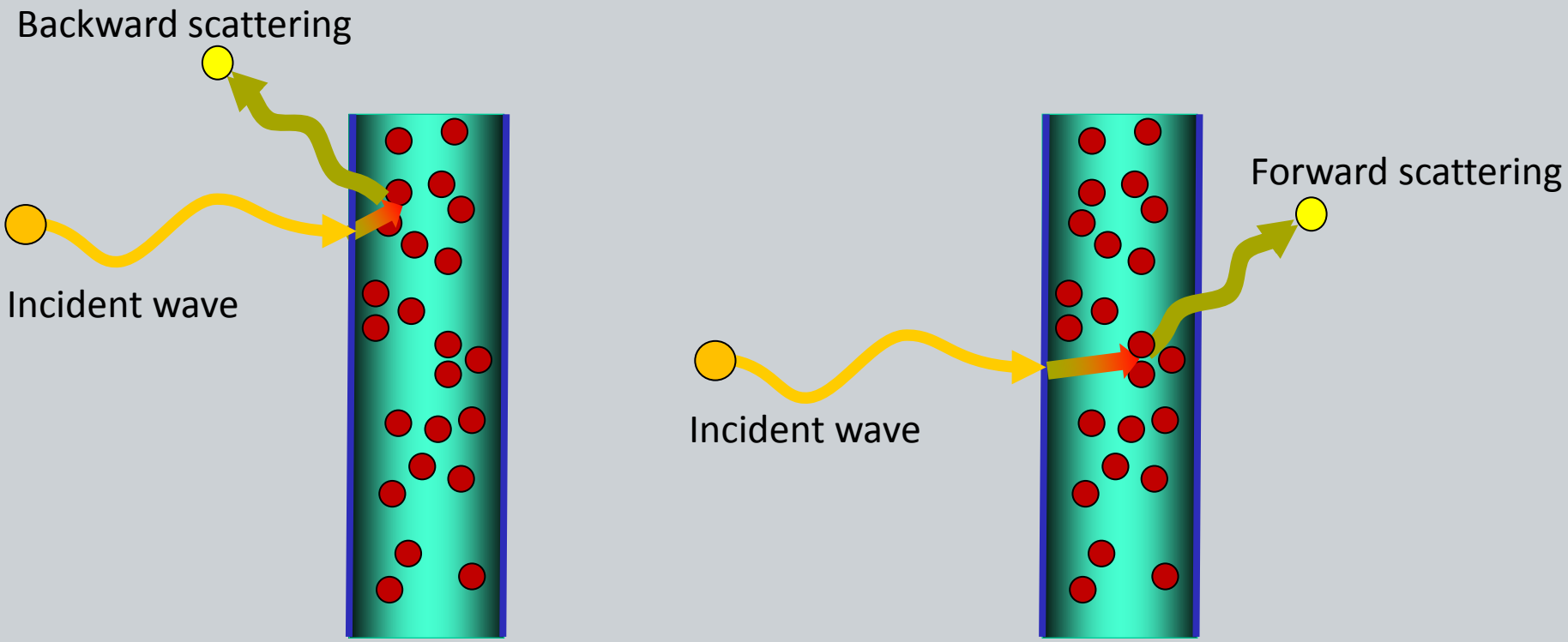
"scattering". Encyclopædia Britannica. Encyclopædia Britannica Online. Encyclopædia Britannica Inc., 2015. Web. 16 Sep. 2015 <http://global.britannica.com/science/scattering>.



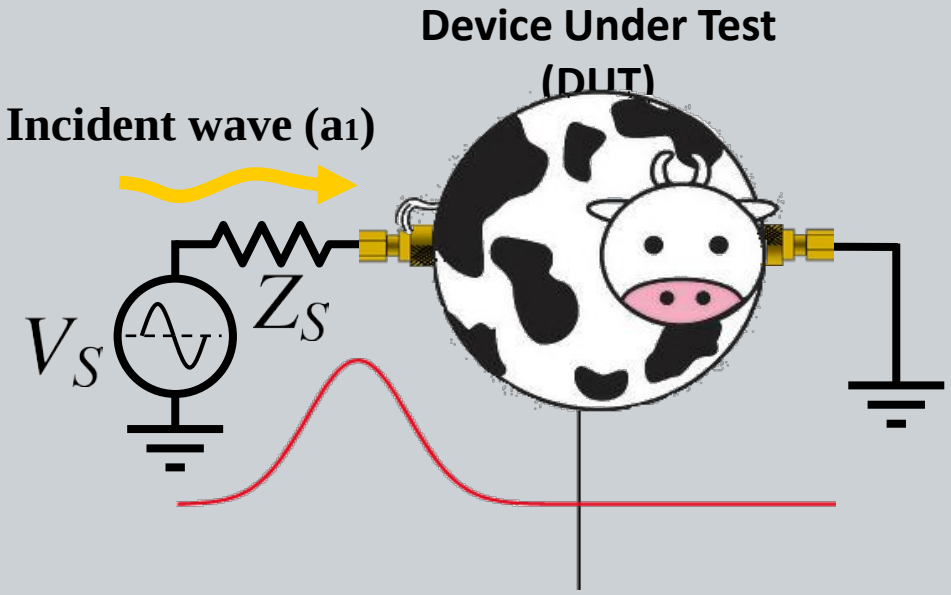
S-Parameters



S-Parameters



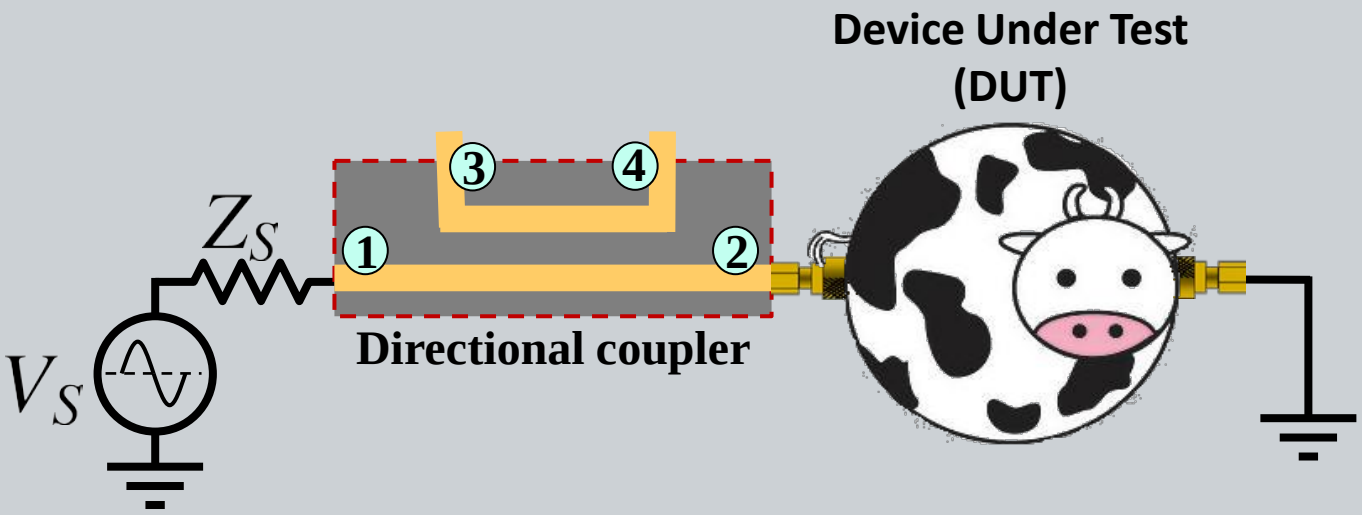
VNA Basics



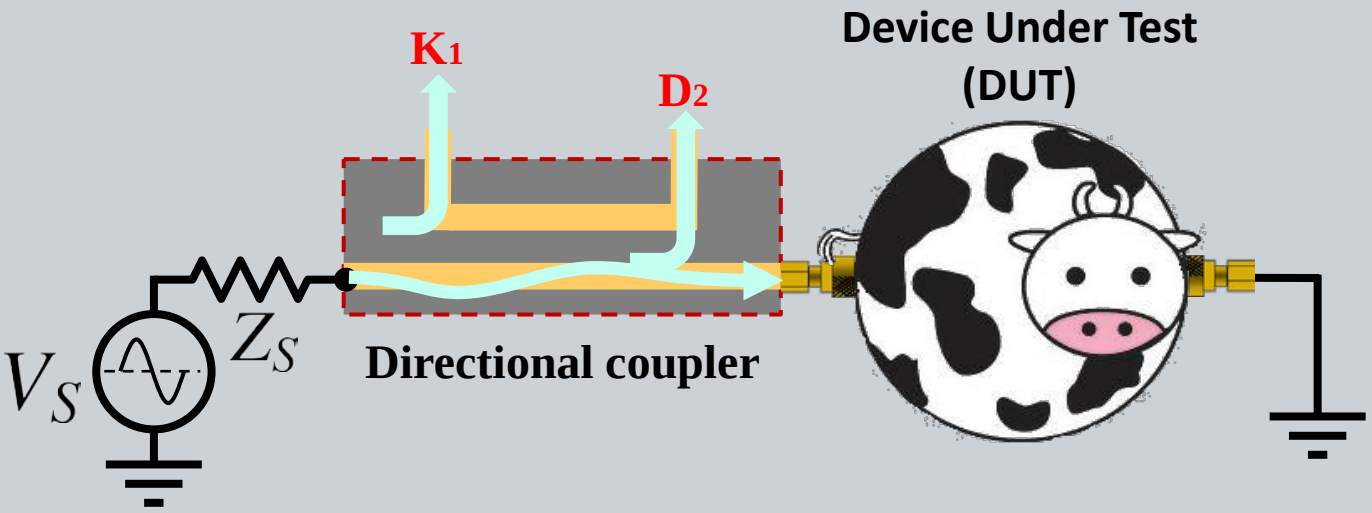
Reflection coefficient

$$\rho = \frac{b_1}{a_1}$$

VNA Basics

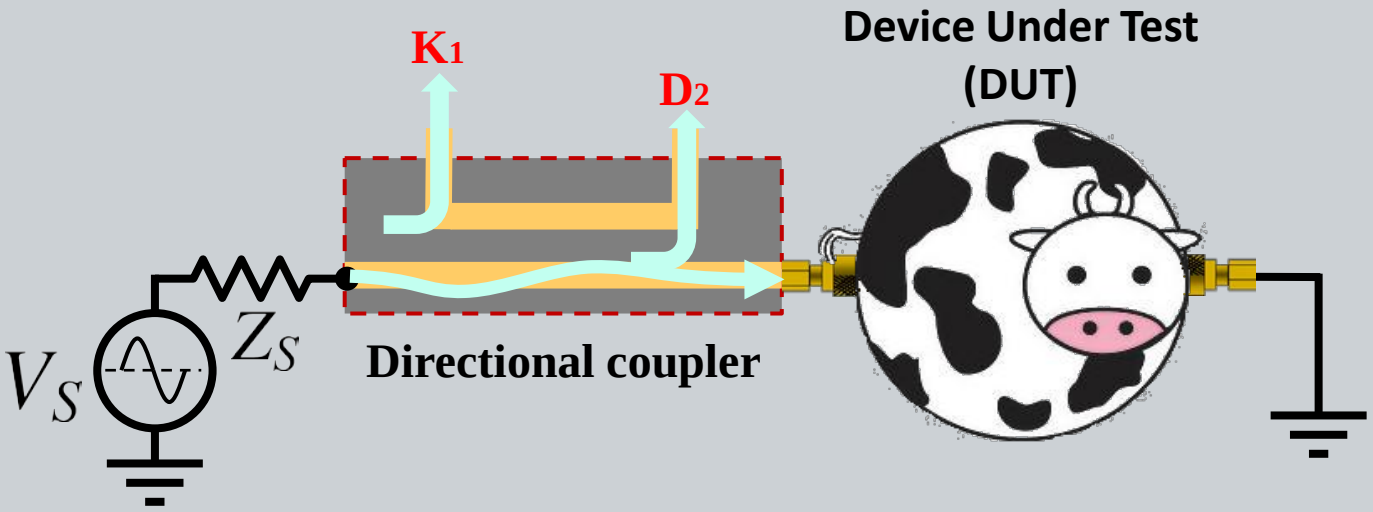


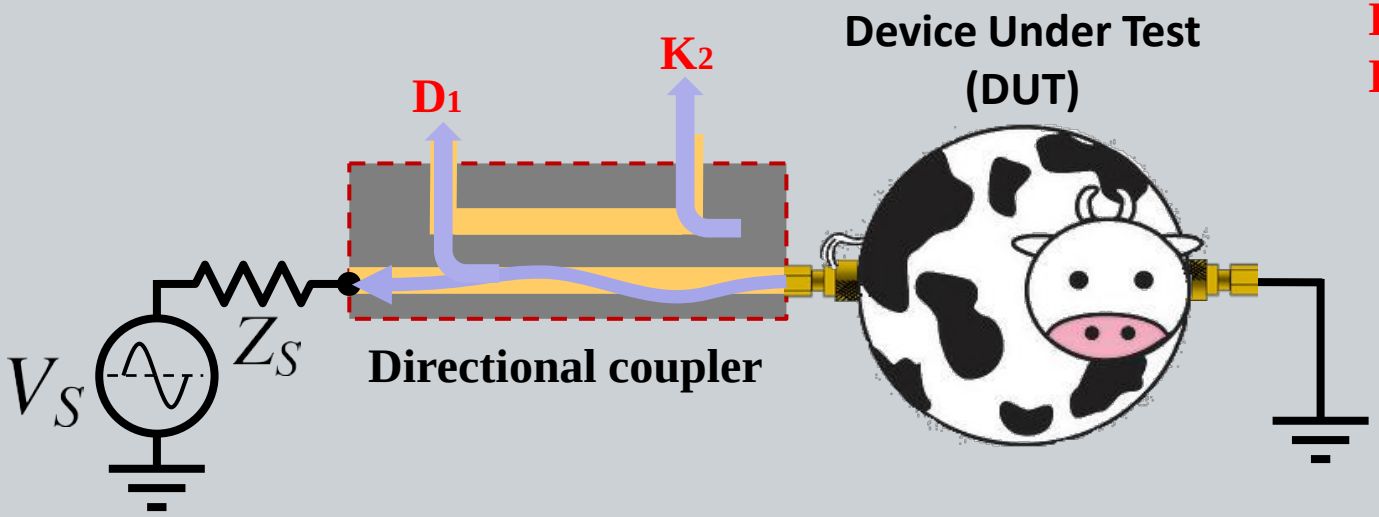
VNA Basics



D_2: Directivity
K_1: Coupling

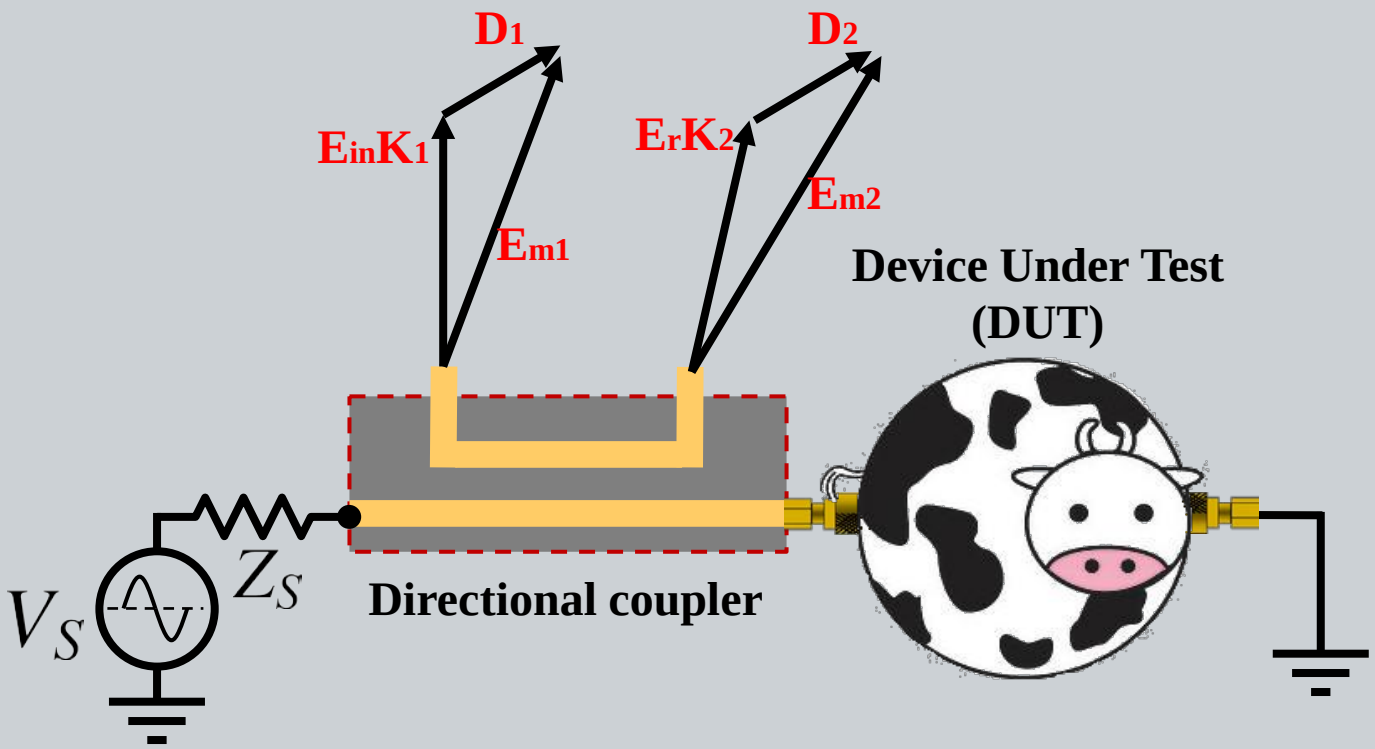
VNA Basics





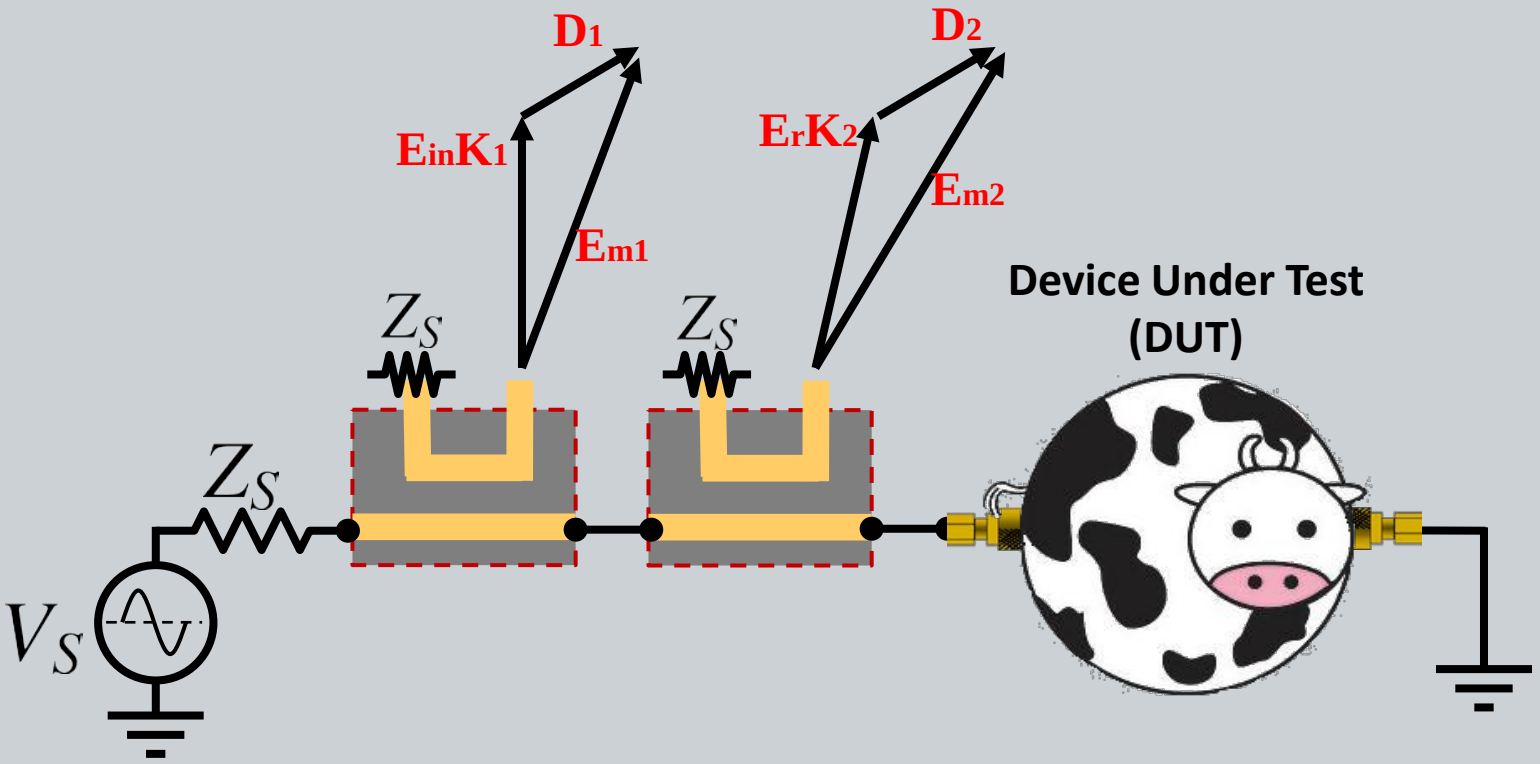
D_1, D_2 : Directivities
K_1, K_2: Coupling

VNA Basics

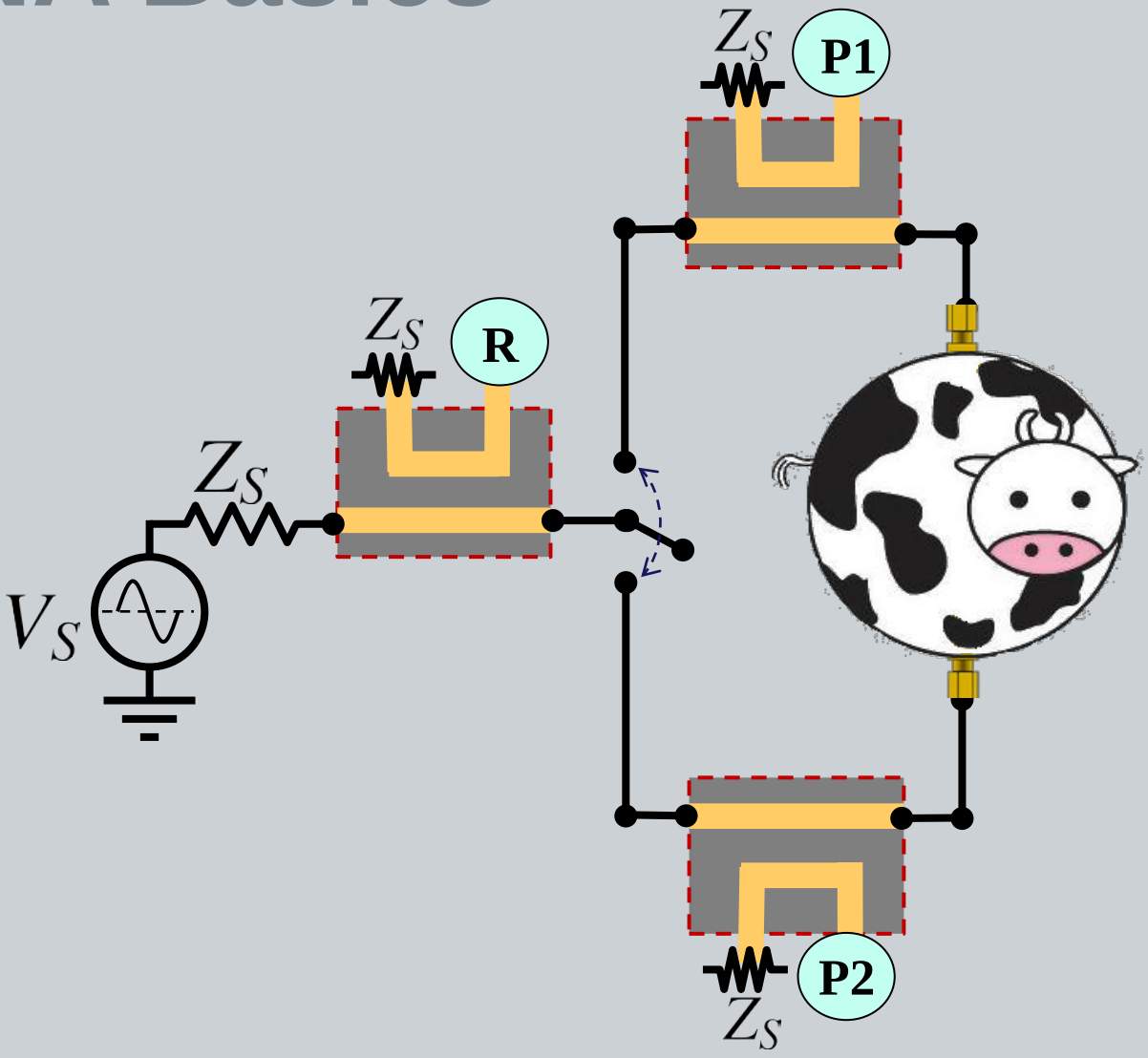


D_1, D_2 : Directivities
K_1, K_2: Coupling
E_{in}: Input Signal
E_r: Reflected Signal
E_m: Measured Signal (Including error)

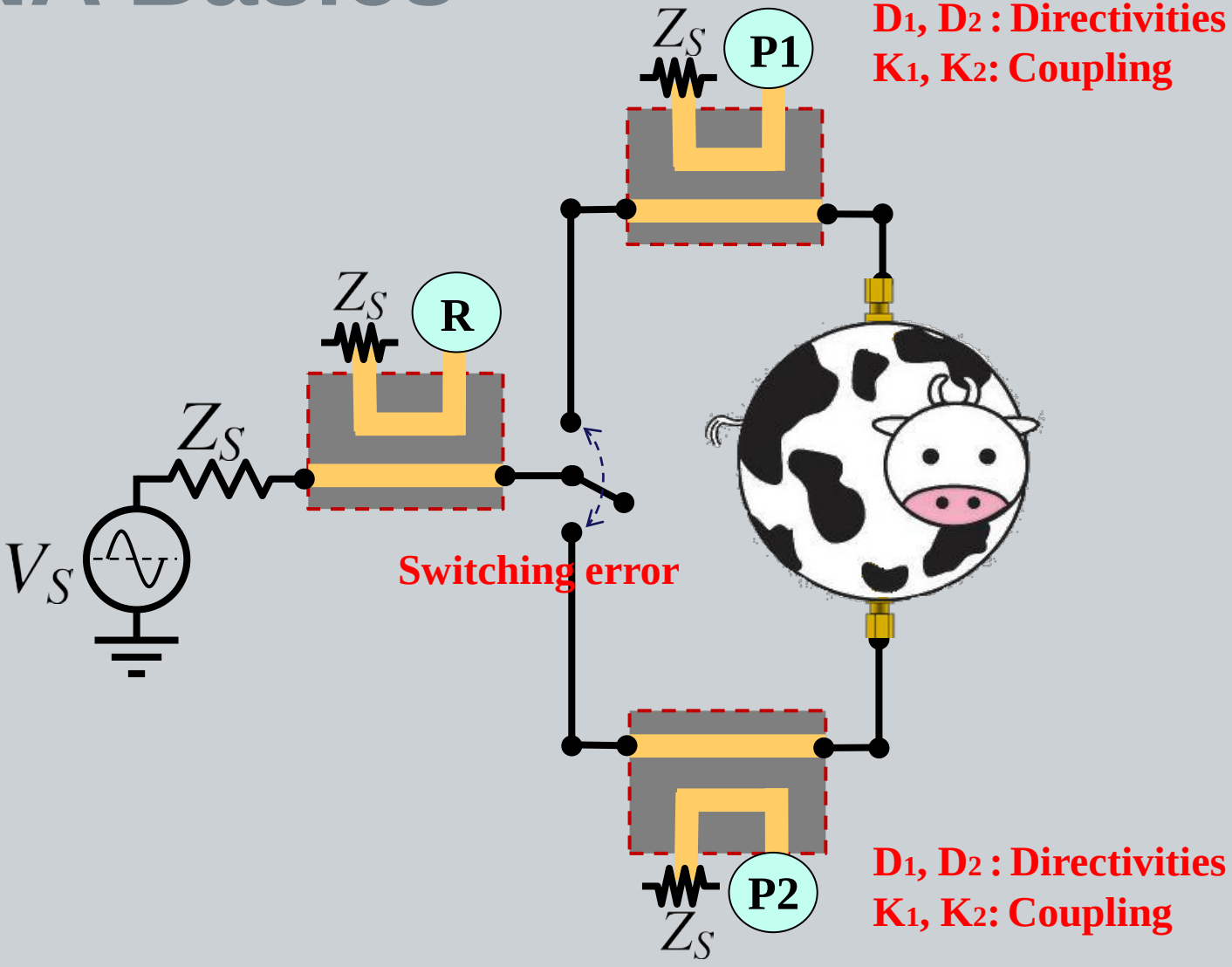
VNA Basics



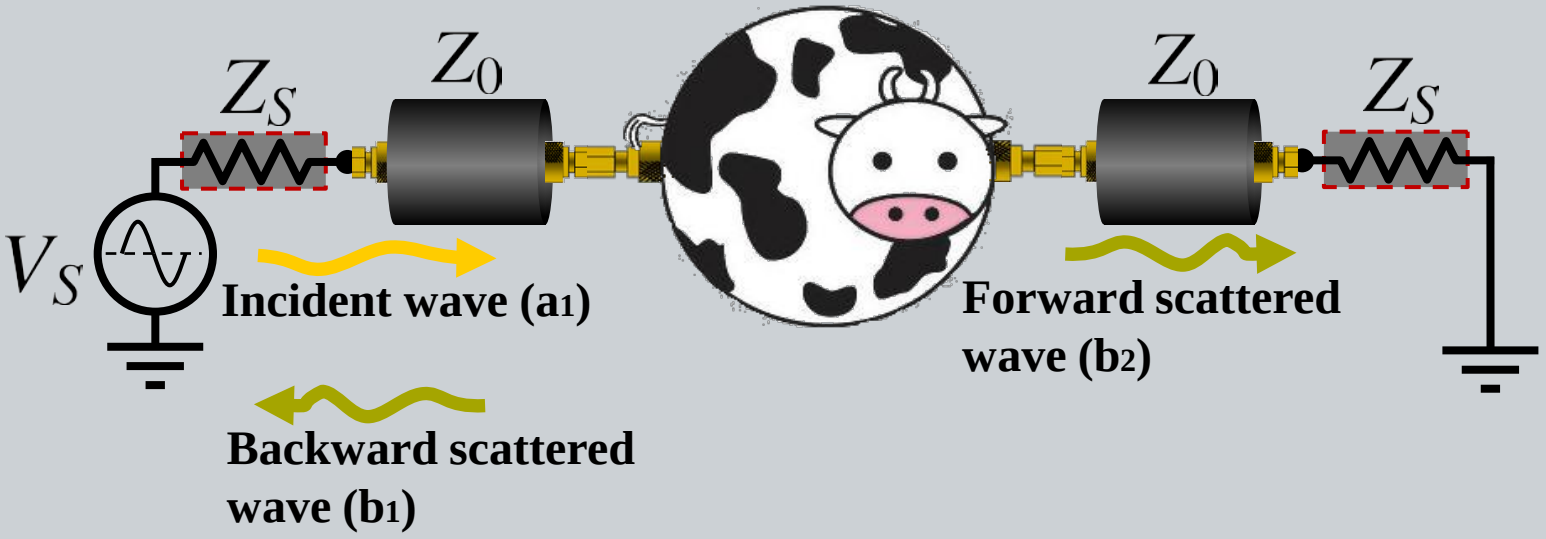
VNA Basics



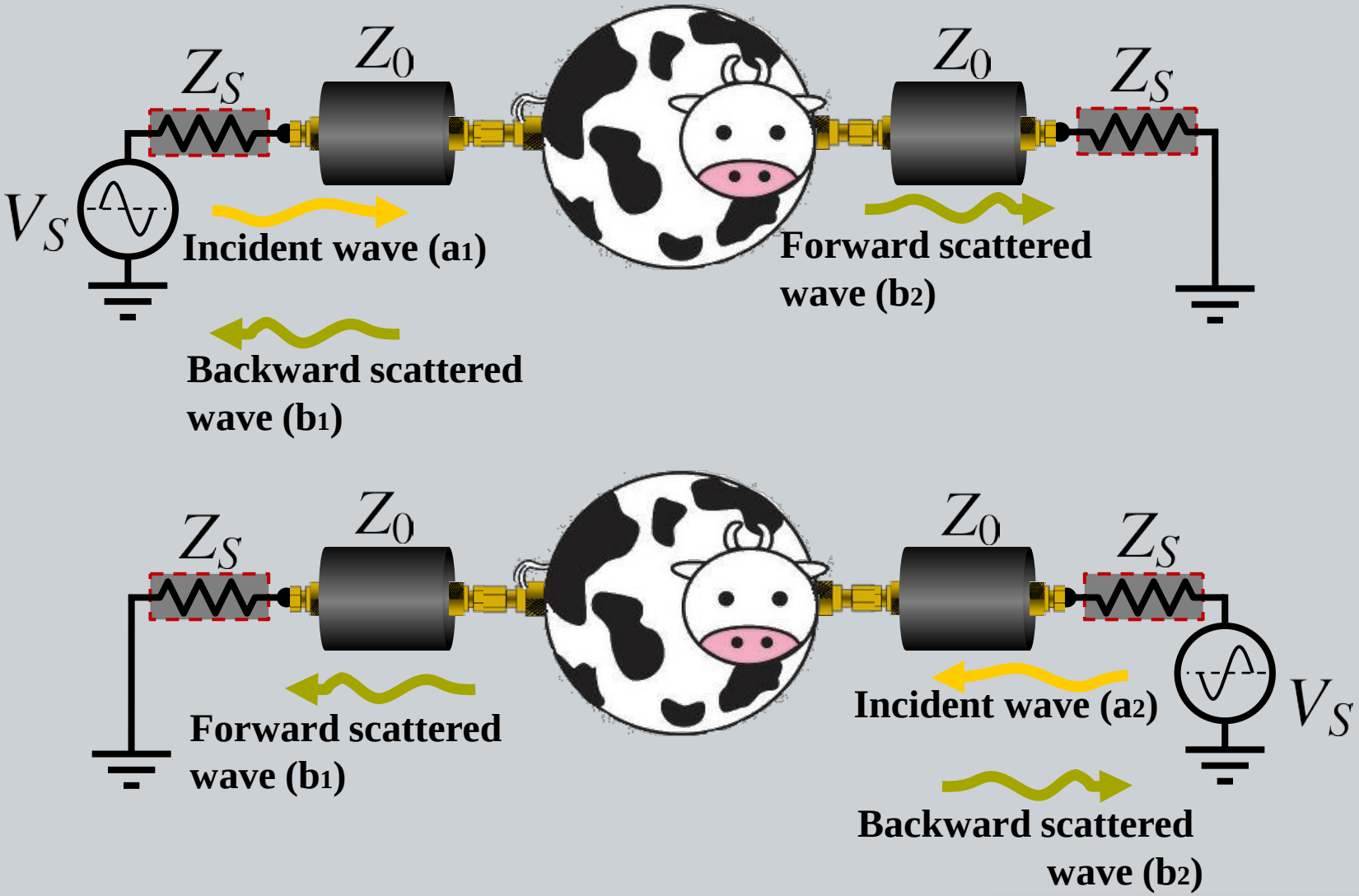
VNA Basics


Z_S
P1
Z_S
R
Z_S
V_S
Switching error
Z_S
P2
D1, D2 : Directivities
K1, K2: Coupling
D1, D2 : Directivities
K1, K2: Coupling

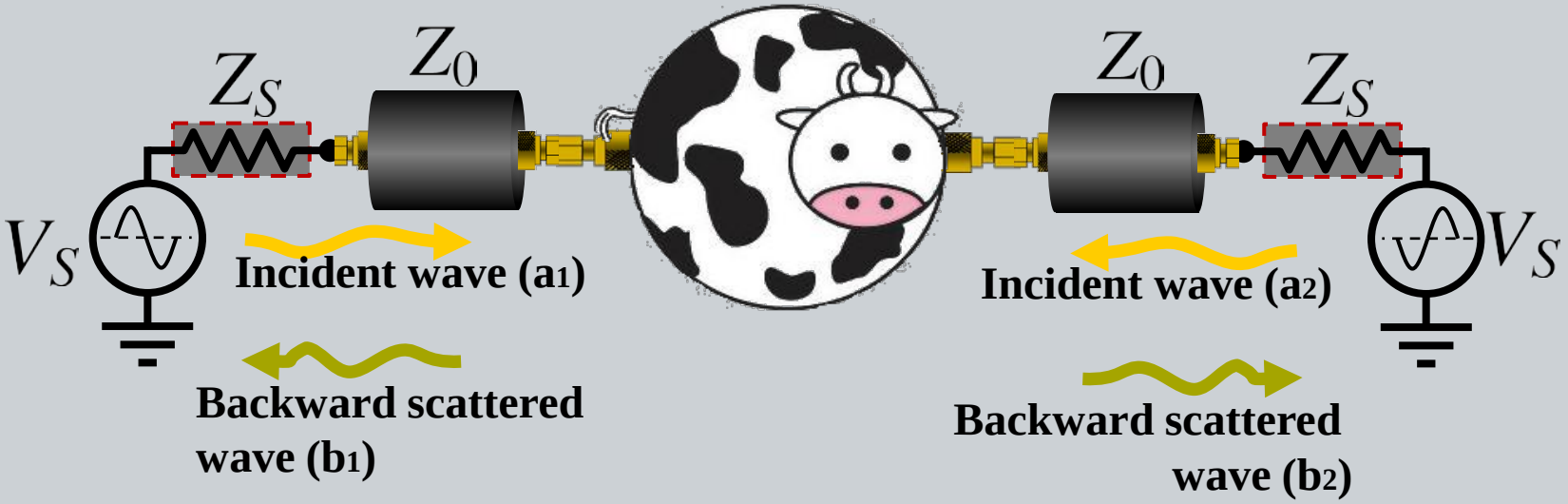
VNA Basics


Z_S
Z_0
Z_0
Z_S
V_S
Incident wave (a_1)
Forward scattered wave (b_2)
Backward scattered wave (b_1)

VNA Basics

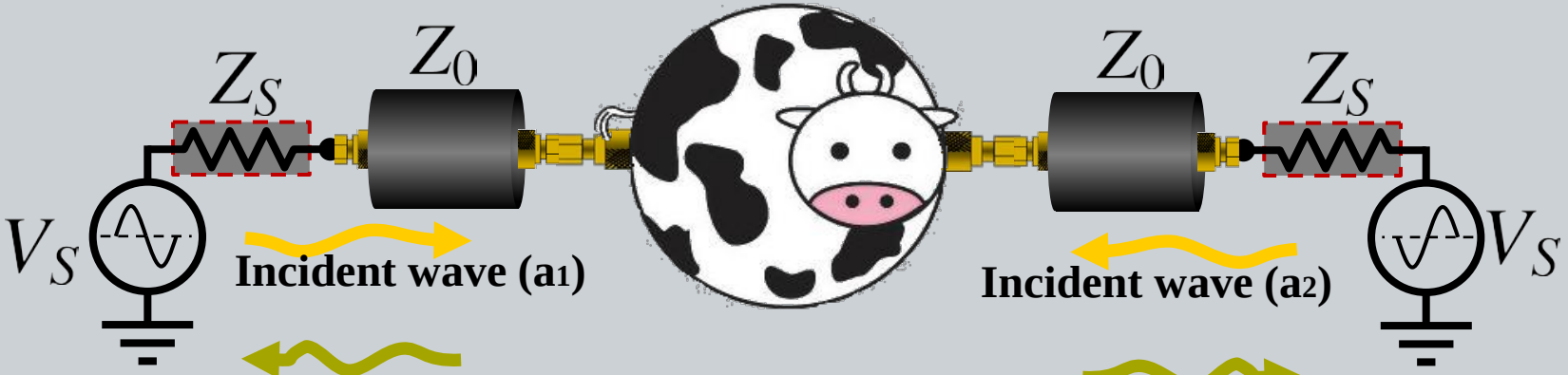

Z_S
Z_0
Z_0
Z_S
V_S
Incident wave (a_1)
Forward scattered wave (b_2)
Backward scattered wave (b_1)
Z_S
Z_0
Z_0
Z_S
Forward scattered wave (b_1)
Incident wave (a_2)
V_S
Backward scattered wave (b_2)

VNA Basics



$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

VNA Basics

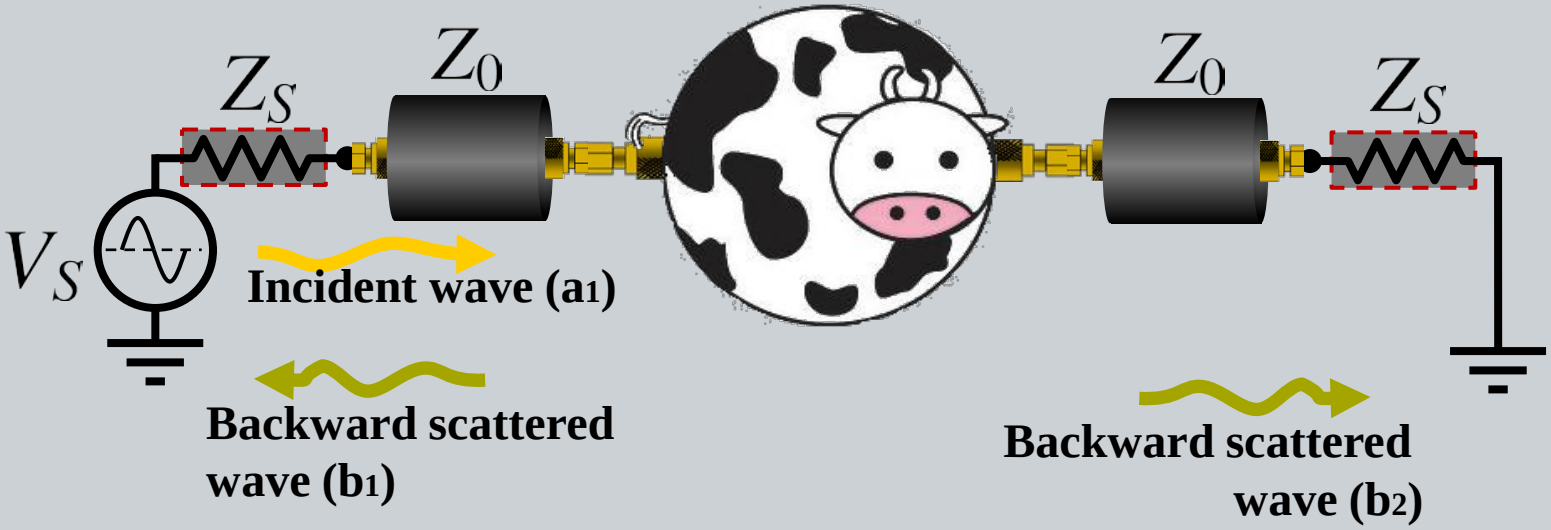


$$s_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0} \qquad s_{12} = \left.\frac{b_1}{a_2}\right|_{a_1=0}$$

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$s_{21} = \left.\frac{b_2}{a_1}\right|_{a_2=0} \qquad s_{22} = \left.\frac{b_2}{a_2}\right|_{a_1=0}$$

VNA Basics

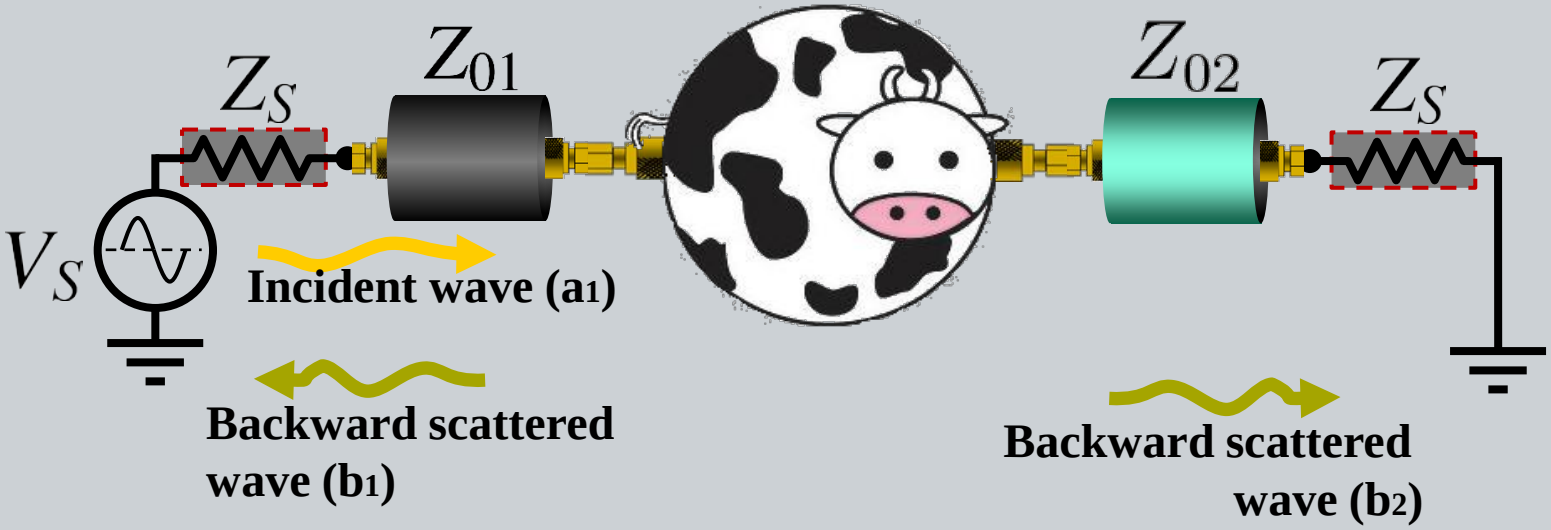


$$s_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0}$$

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$s_{21} = \left.\frac{b_2}{a_1}\right|_{a_2=0}$$

VNA Basics

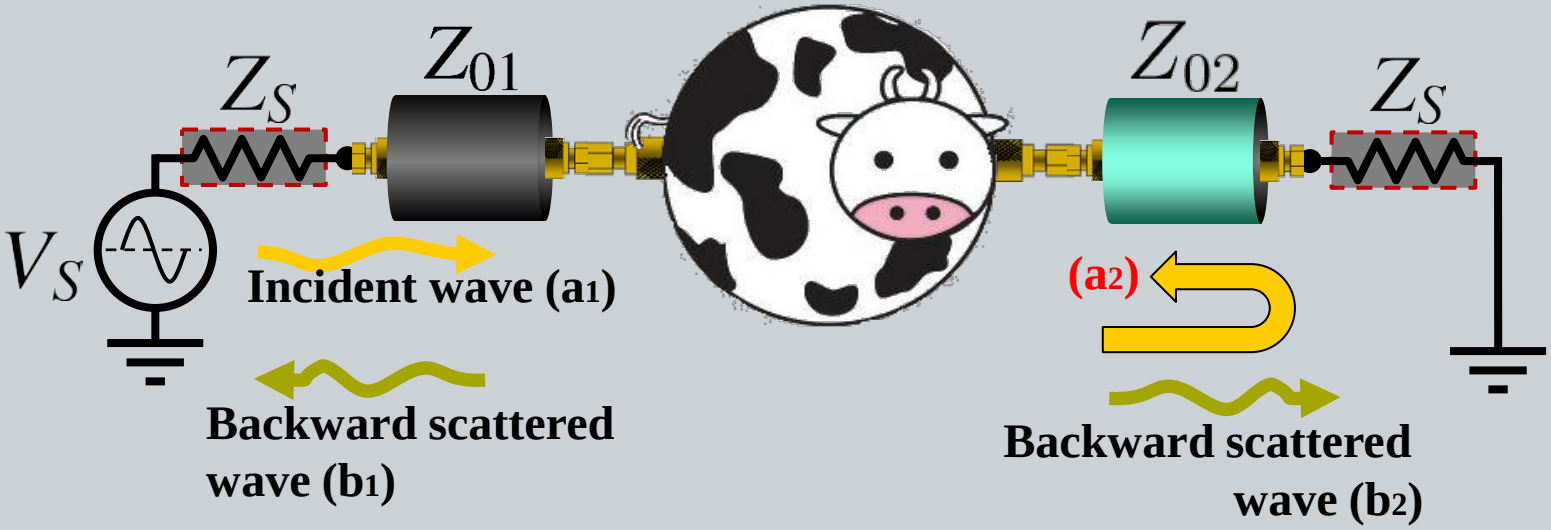


$$s_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0}$$

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$s_{21} = \left.\frac{b_2}{a_1}\right|_{a_2=0}$$

VNA Basics

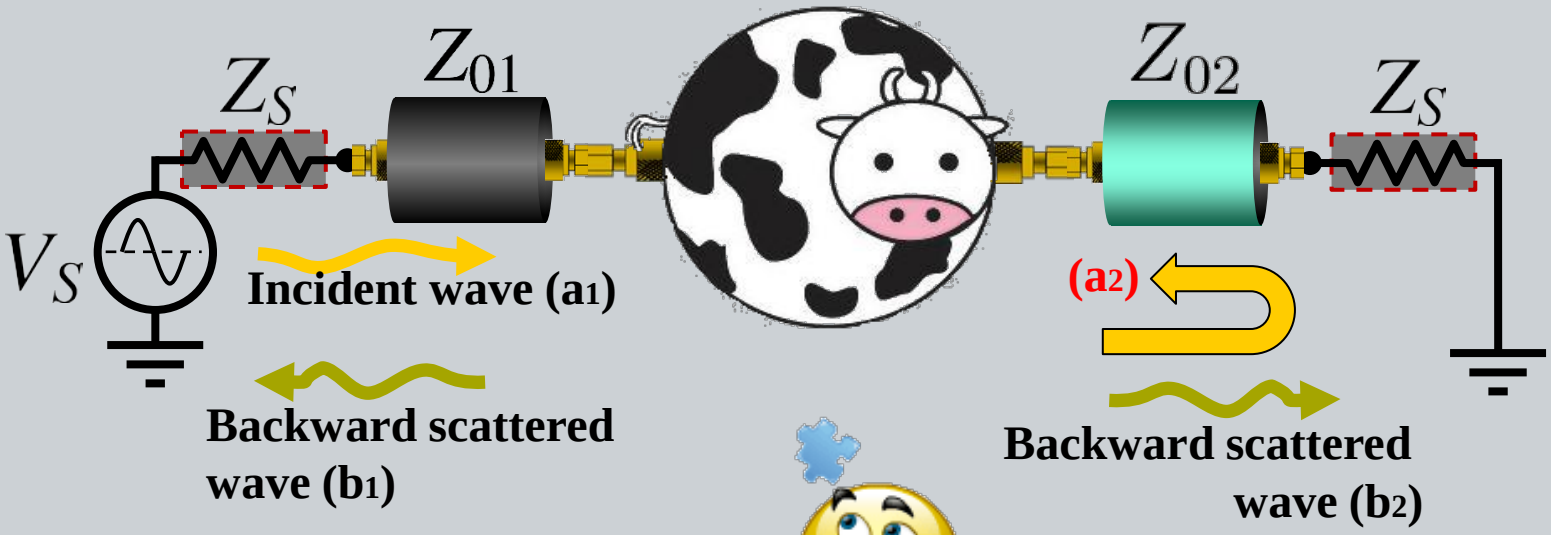


$$s_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0}$$

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$s_{21} = \left.\frac{b_2}{a_1}\right|_{a_2=0}$$

VNA Basics

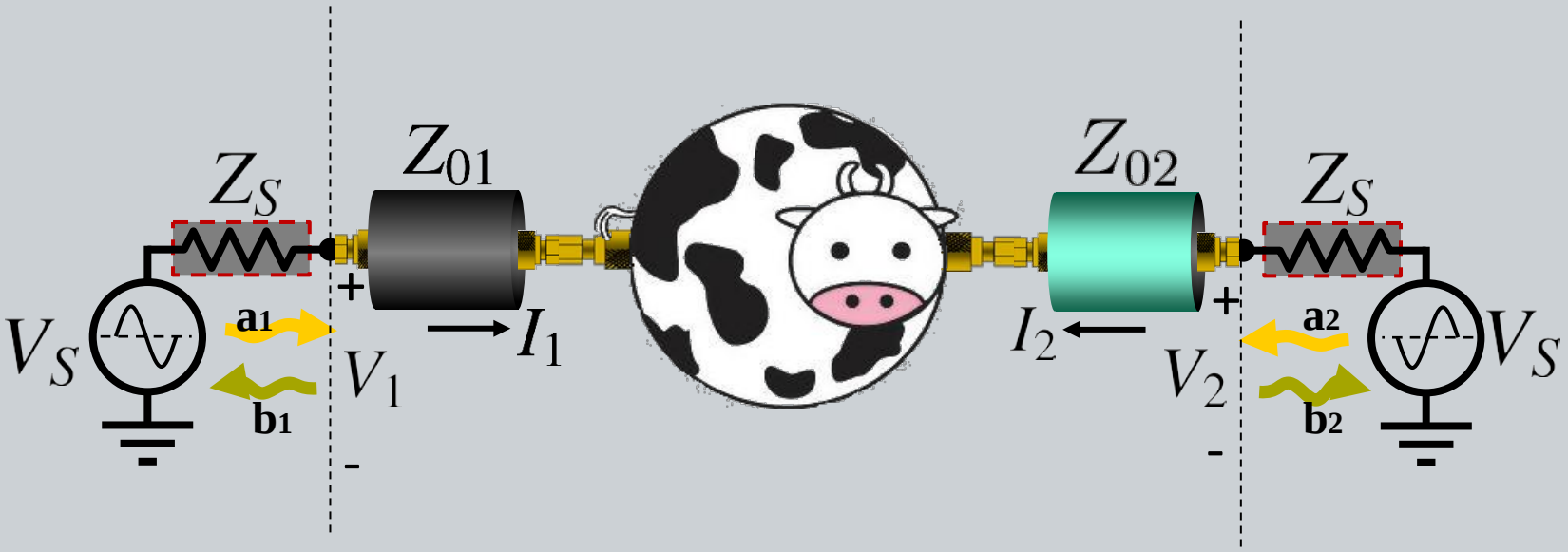


$$s_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0}$$

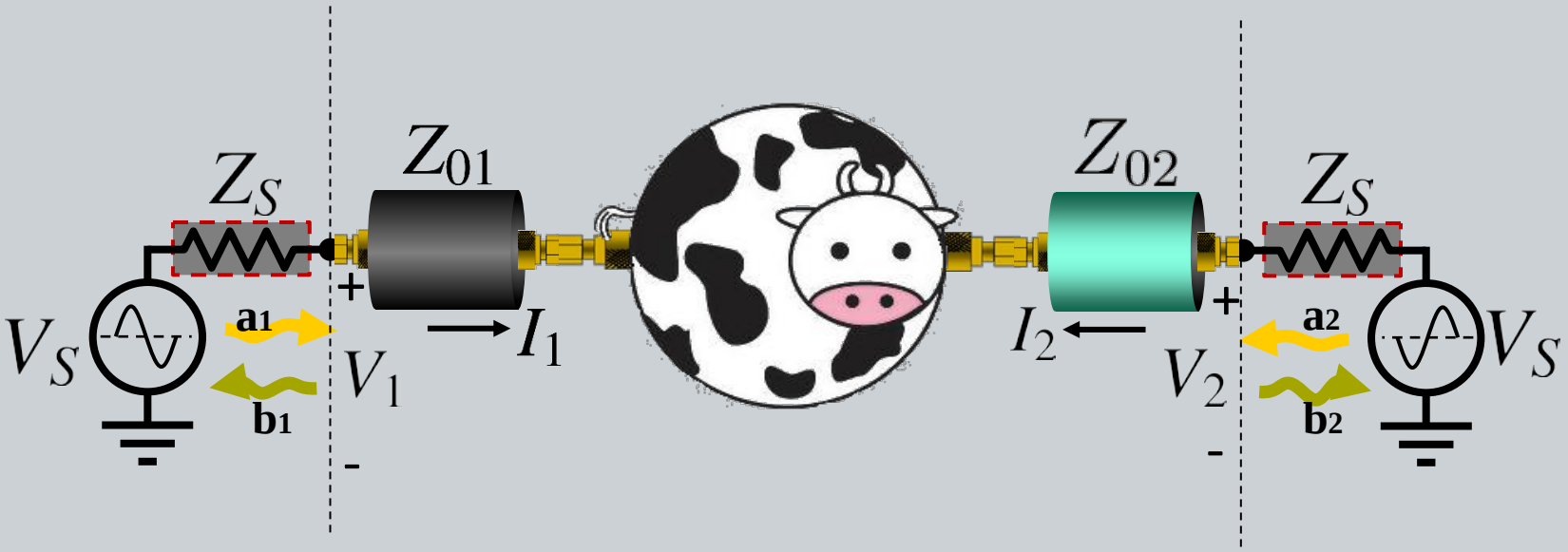
$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$s_{21} = \left.\frac{b_2}{a_1}\right|_{a_2=0}$$

VNA Basics



VNA Basics



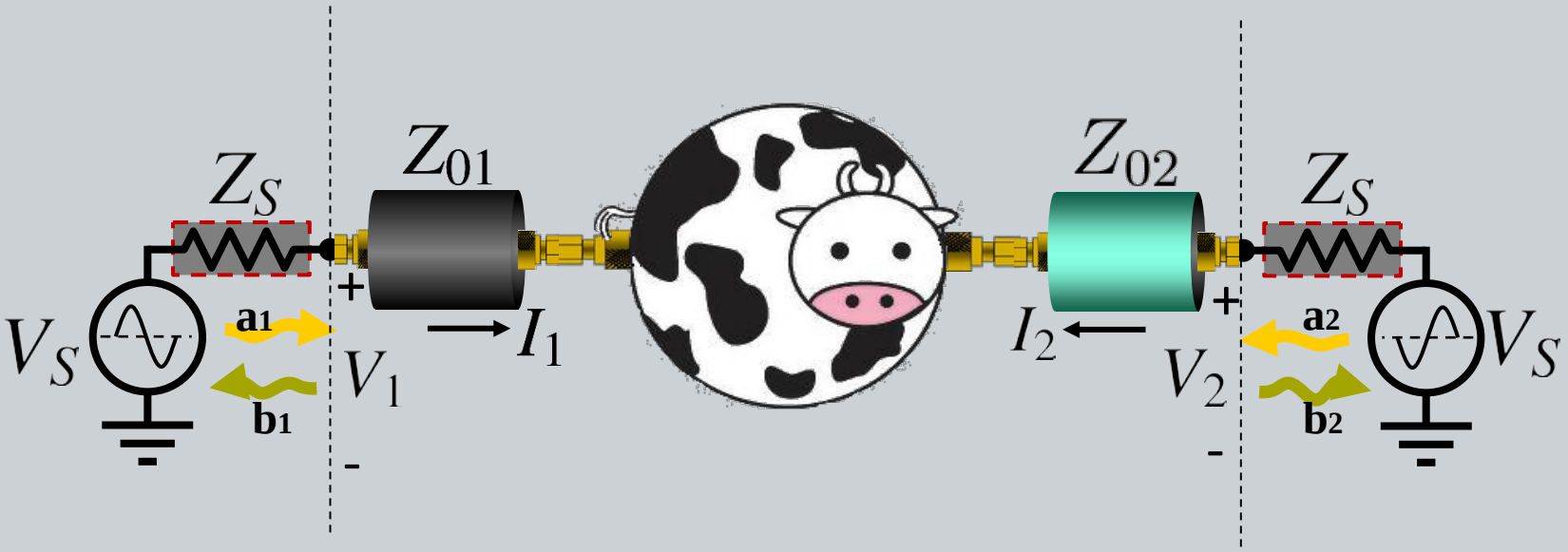
$$b_1 = \frac{V_1 - Z_{01} I_1}{2\sqrt{Z_{01}}}$$

$$b_2 = \frac{V_2 - Z_{02} I_2}{2\sqrt{Z_{02}}}$$

$$a_1 = \frac{V_1 + Z_{01} I_1}{2\sqrt{Z_{01}}}$$

$$a_2 = \frac{V_2 + Z_{02} I_2}{2\sqrt{Z_{02}}}$$

VNA Basics



$$b_1 = \frac{V_1 - Z_{01} I_1}{2\sqrt{Z_{01}}}$$

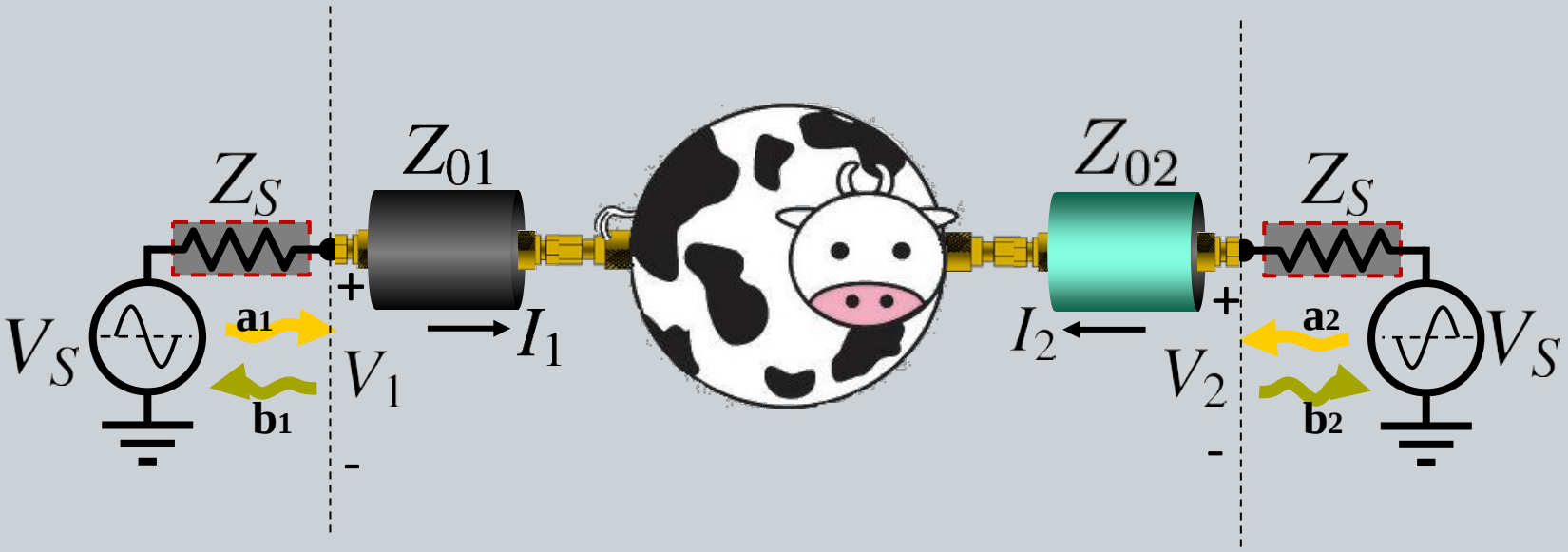
$$s_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0}$$

$$b_2 = \frac{V_2 - Z_{02} I_2}{2\sqrt{Z_{02}}}$$

$$a_1 = \frac{V_1 + Z_{01} I_1}{2\sqrt{Z_{01}}}$$

$$a_2 = \frac{V_2 + Z_{02} I_2}{2\sqrt{Z_{02}}}$$

VNA Basics

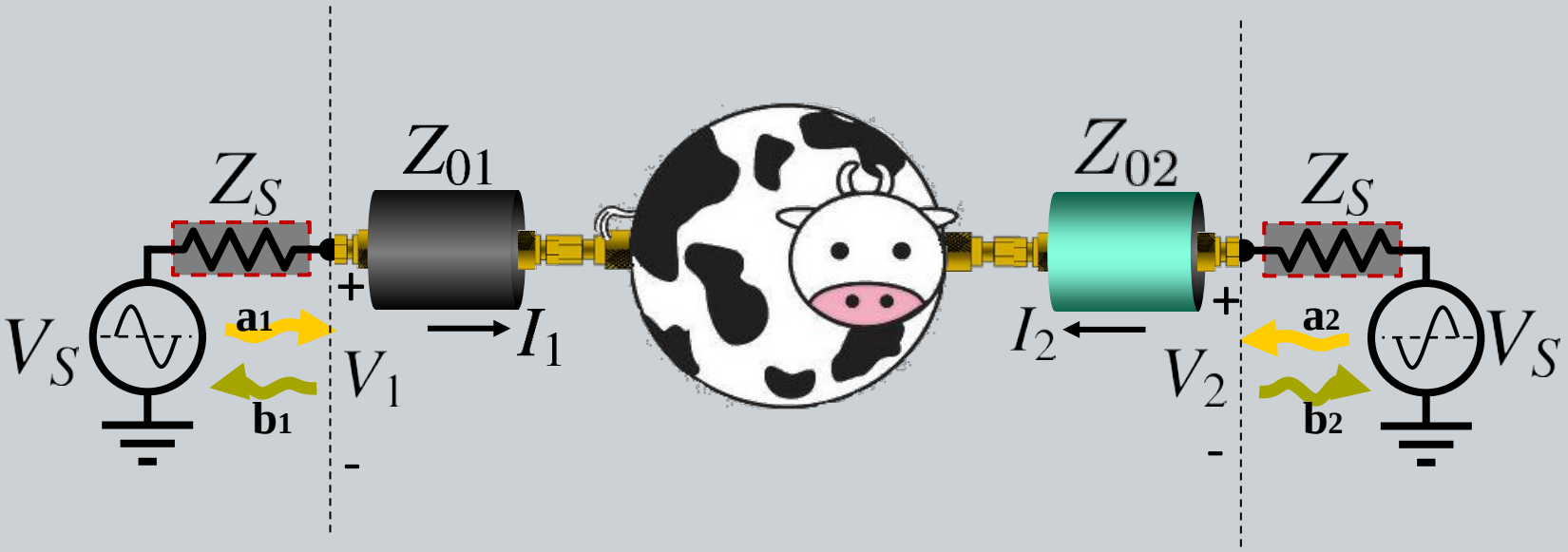


$$b_1 = \frac{V_1 - Z_{01} I_1}{2\sqrt{Z_{01}}}$$

$$a_1 = \frac{V_1 + Z_{01} I_1}{2\sqrt{Z_{01}}}$$

$$s_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0}$$

VNA Basics



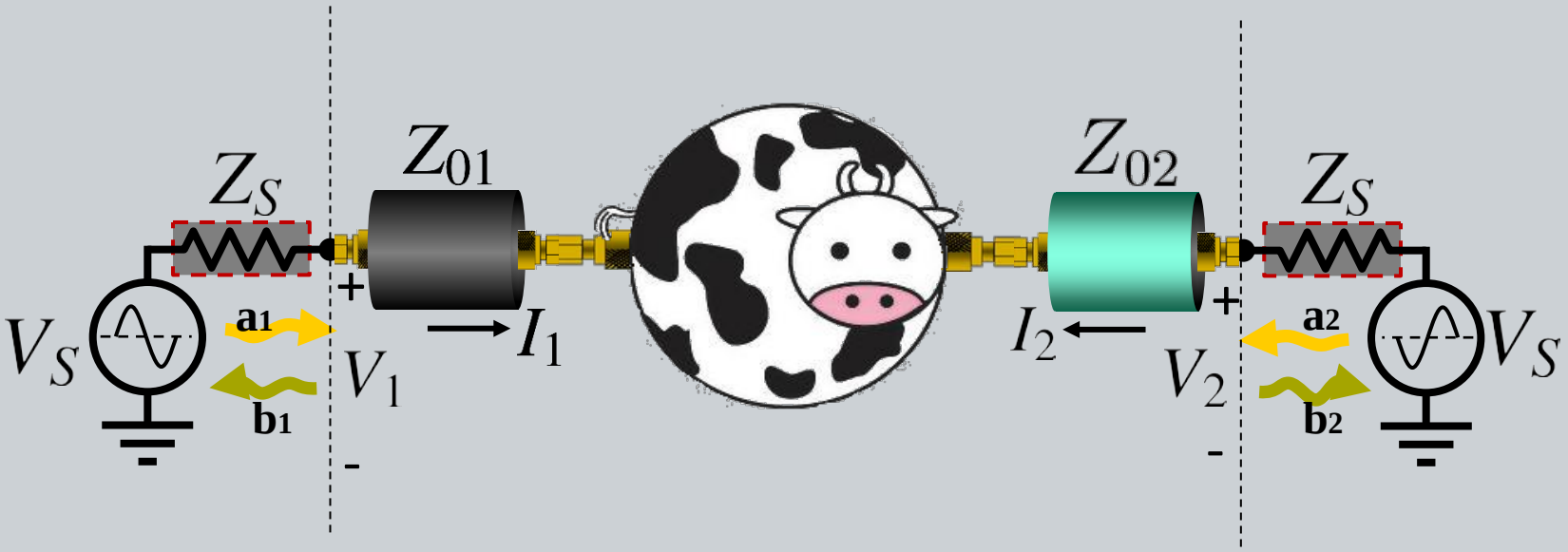
$$b_1 = \frac{V_1 - Z_{01} I_1}{2\sqrt{Z_{01}}}$$

$$a_1 = \frac{V_1 + Z_{01} I_1}{2\sqrt{Z_{01}}}$$

$$s_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0}$$

$$S_{11} = \frac{Z_{in} - Z_{01}}{Z_{in} + Z_{01}}$$

VNA Basics



$$b_1 = \frac{V_1 - Z_{01} I_1}{2\sqrt{Z_{01}}}$$

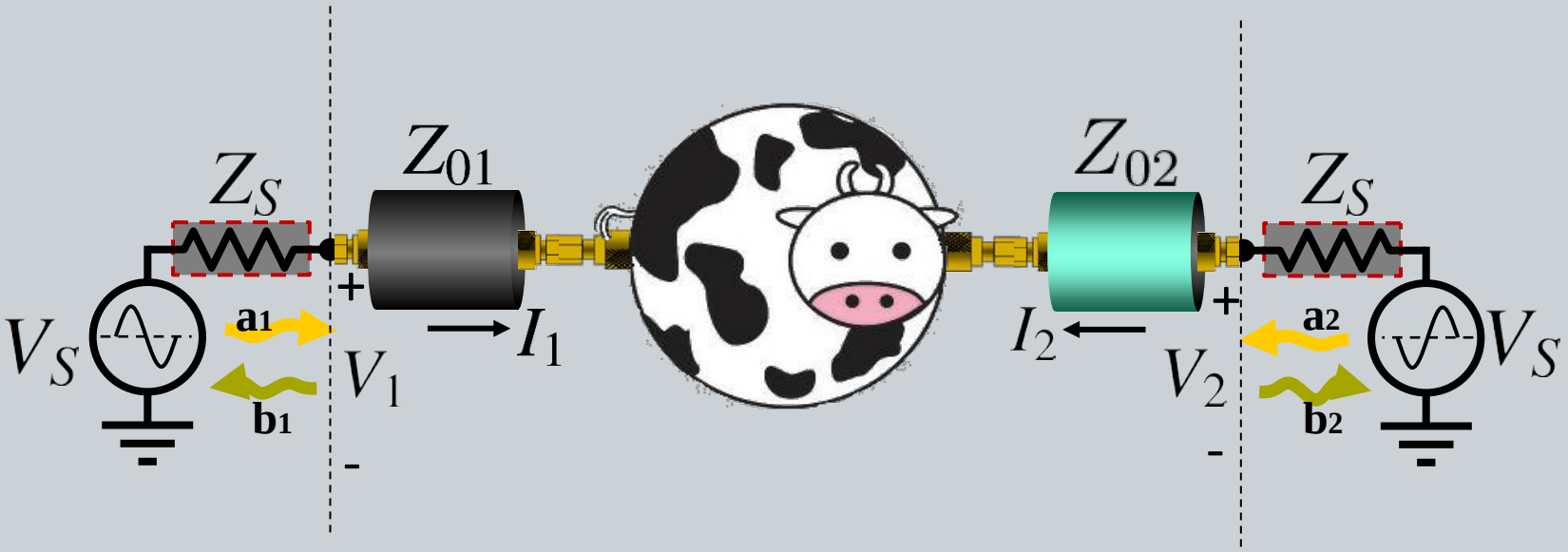
$$a_1 = \frac{V_1 + Z_{01} I_1}{2\sqrt{Z_{01}}}$$

$$a_2 = \frac{V_2 + Z_{02} I_2}{2\sqrt{Z_{02}}}$$

$$s_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0}$$

$$S_{11} = \frac{Z_{in} - Z_{01}}{Z_{in} + Z_{01}}$$

VNA Basics



$$b_1 = \frac{V_1 - Z_{01} I_1}{2\sqrt{Z_{01}}}$$

$$a_1 = \frac{V_1 + Z_{01} I_1}{2\sqrt{Z_{01}}}$$

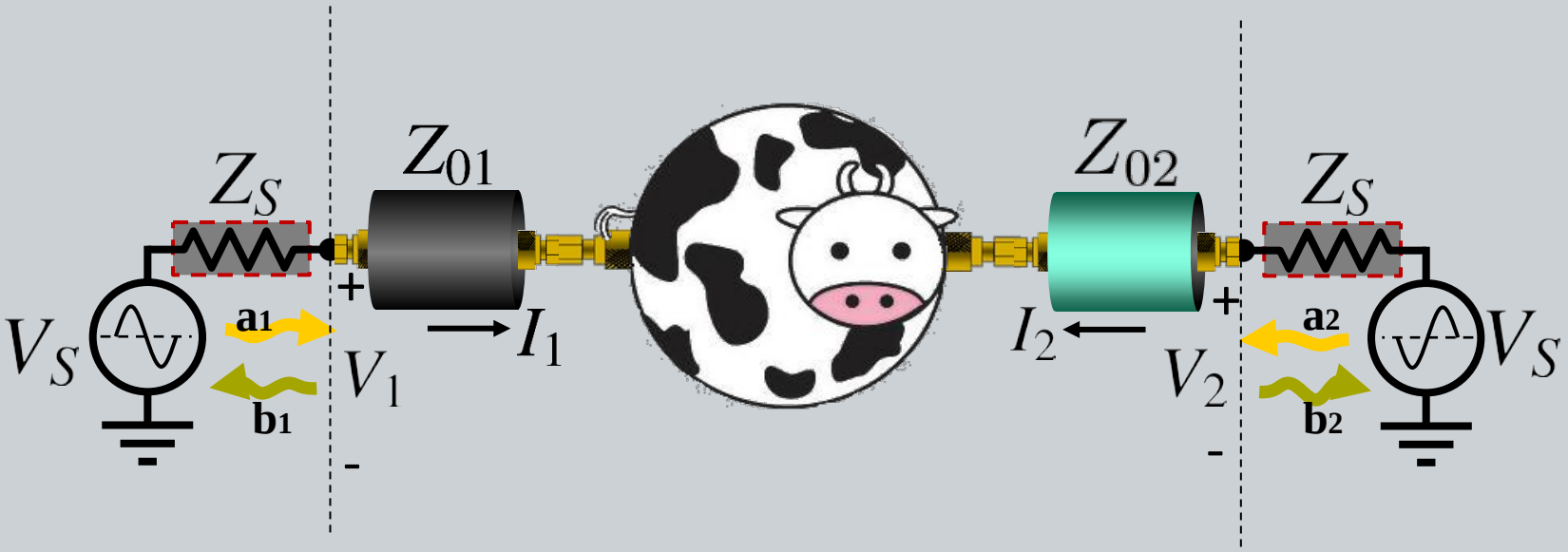
$$s_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0}$$

$$S_{11} = \frac{Z_{in} - Z_{01}}{Z_{in} + Z_{01}}$$

$$a_2 = \frac{V_2 + Z_{02} I_2}{2\sqrt{Z_{02}}}$$

$$V_2 = -Z_{02} I_2$$

VNA Basics



$$b_1 = \frac{V_1 - Z_{01} I_1}{2\sqrt{Z_{01}}}$$

$$a_1 = \frac{V_1 + Z_{01} I_1}{2\sqrt{Z_{01}}}$$

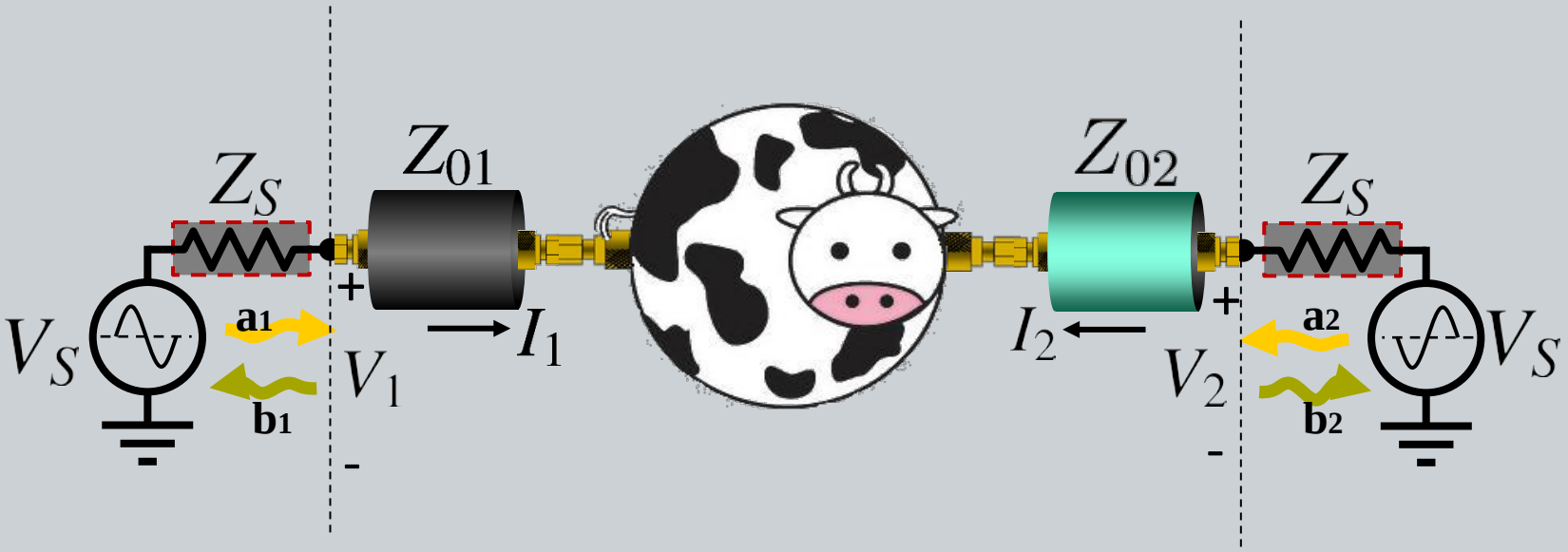
$$s_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0}$$

$$a_2 = \frac{V_2 + Z_{02} I_2}{2\sqrt{Z_{02}}}$$

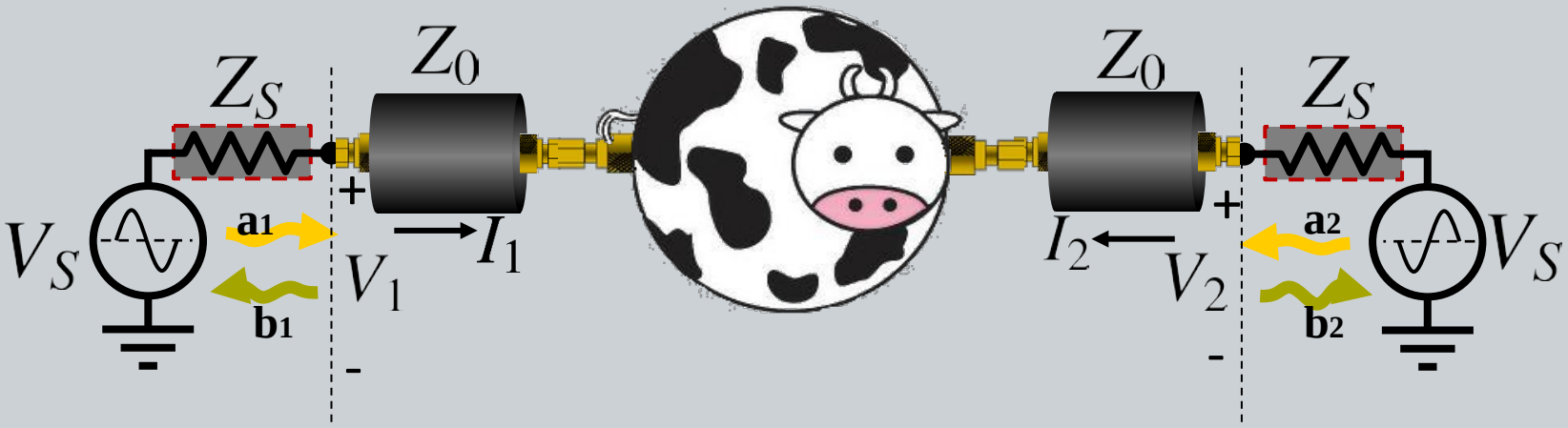
$$V_2 = -Z_{02} I_2$$

$$S_{11} = \left.\frac{Z_{in} - Z_{01}}{Z_{in} + Z_{01}}\right|_{Z_{out}=Z_{02}^*}$$

VNA Basics



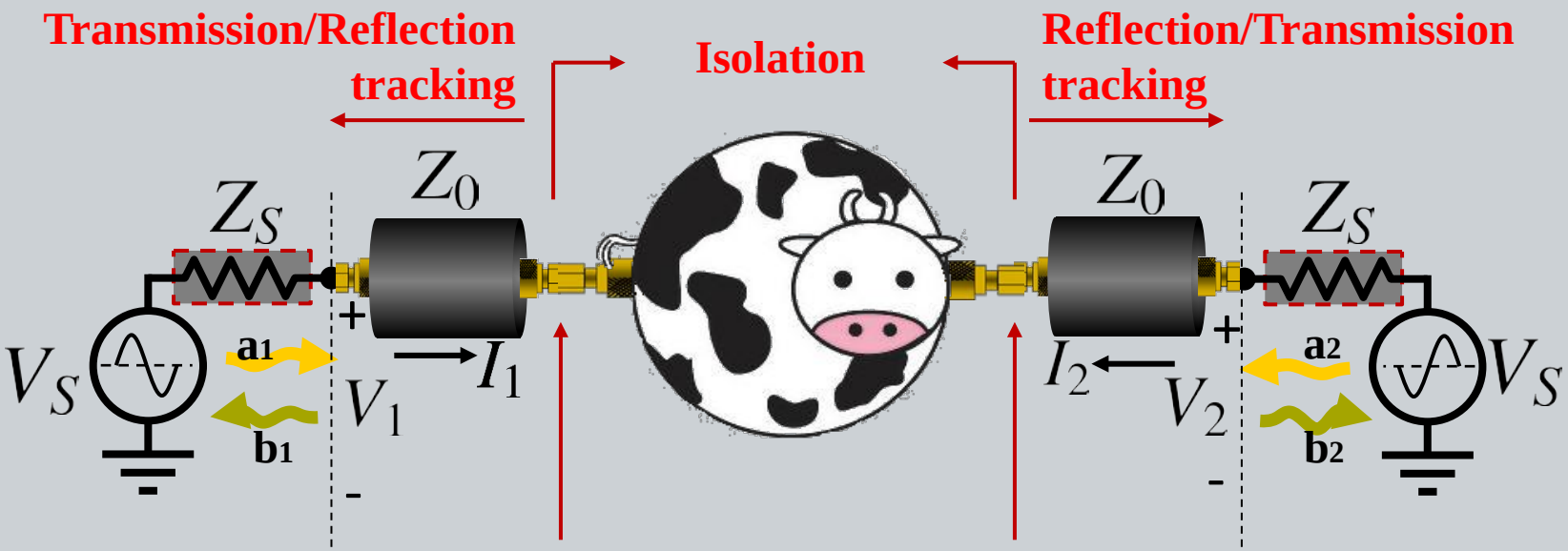
VNA Basics



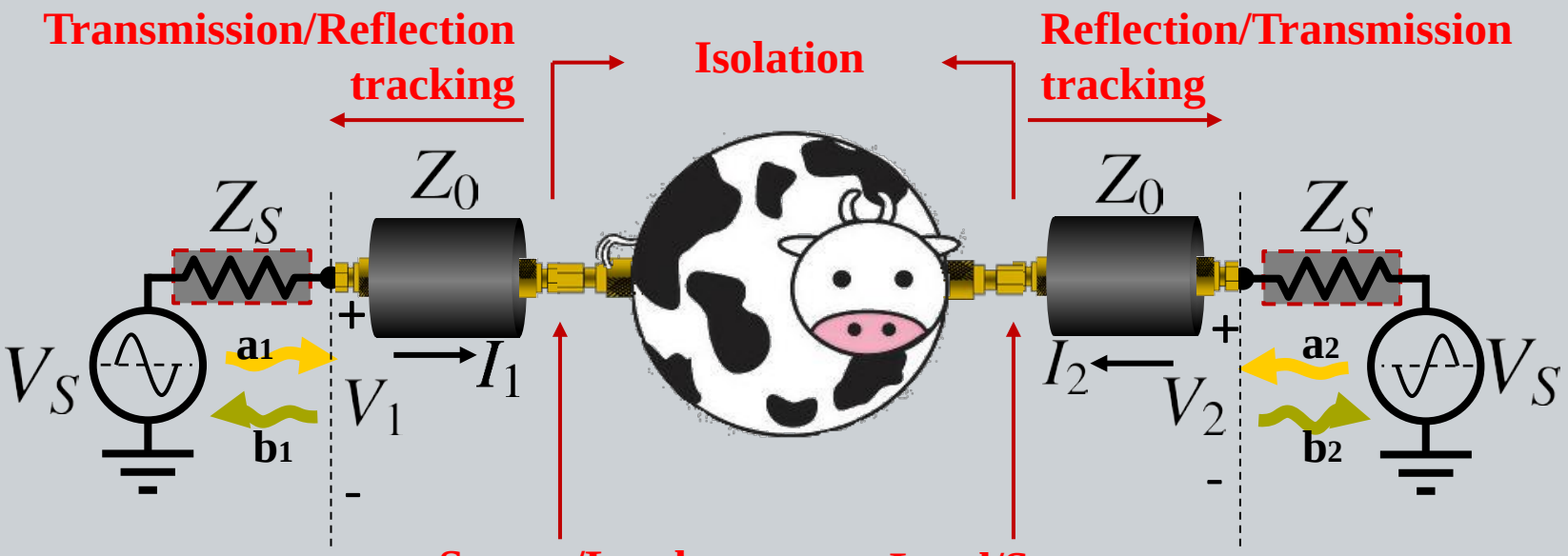
Switching
Directivities
Coupling

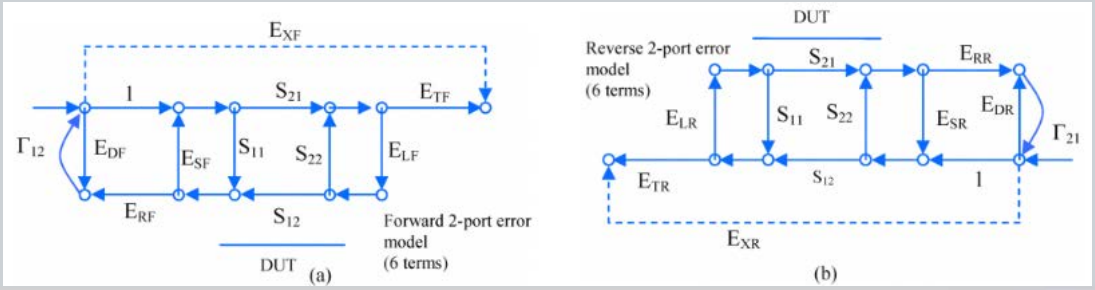
Switching
Directivities
Coupling

VNA Basics

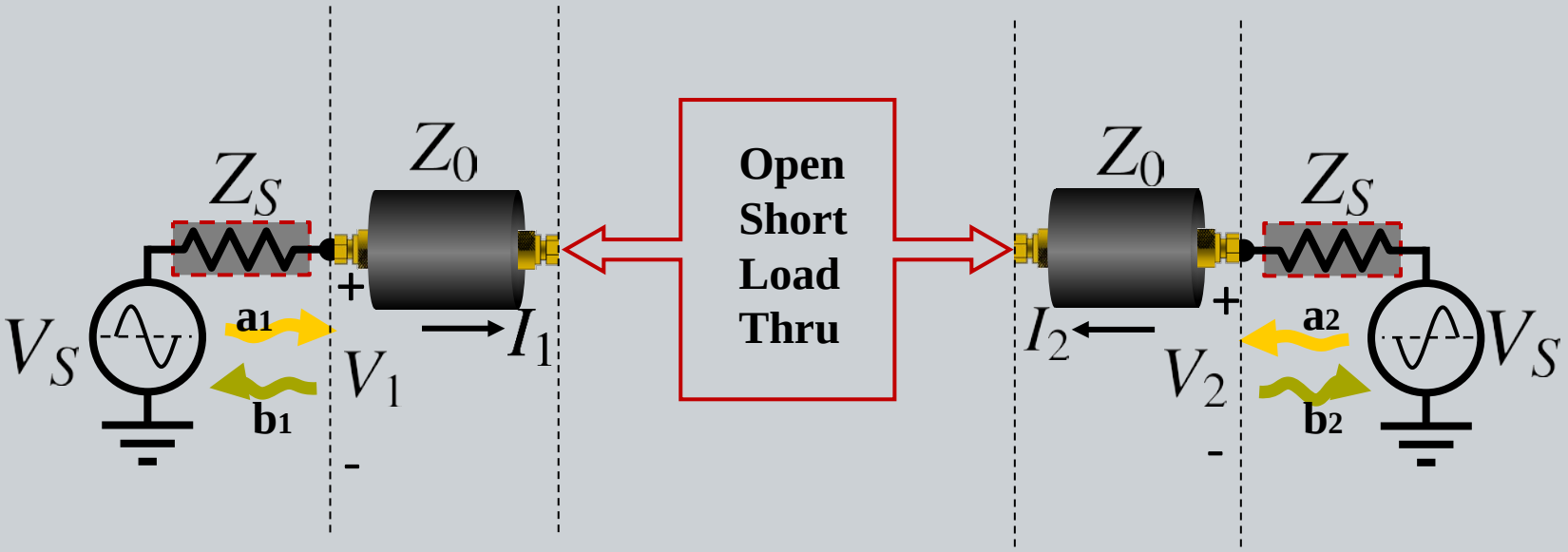

Transmission/Reflection tracking
Isolation
Reflection/Transmission tracking
Z_S
Z_0
Z_0
Z_S
V_S
a1
b1
V_1
I_1
+
-
I_2
V_2
+
-
a2
b2
V_S
Switching Directivities Coupling
Source/Load Match
Load/Source Match
Switching Directivities Coupling

VNA Basics

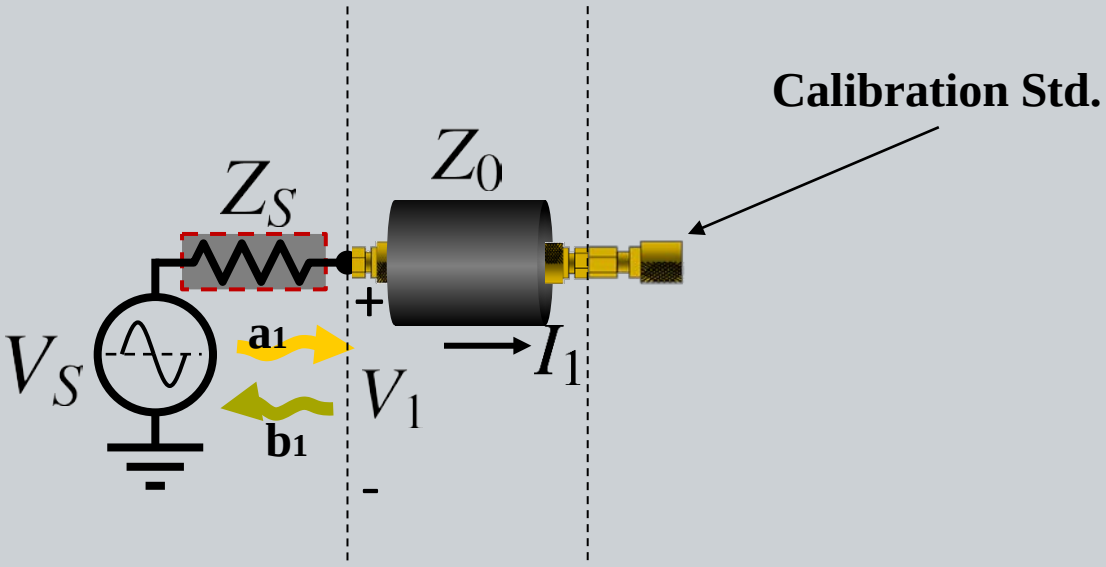

Transmission/Reflection tracking
Isolation
Reflection/Transmission tracking
Z_S
Z_0
Z_0
Z_S
V_S
a1
b1
V_1
I_1
I_2
V_2
a2
b2
V_S
+
-
+
-
Switching Directivities Coupling
Source/Load Match
Load/Source Match
Switching Directivities Coupling


E_{XF}
1
S_{21}
E_{TF}
Γ_{12}
E_{DF}
E_{SF}
S_{11}
S_{22}
E_{LF}
E_{RF}
S_{12}
DUT
(a)
Forward 2-port error model (6 terms)
DUT
Reverse 2-port error model (6 terms)
S_{21}
E_{RR}
E_{LR}
S_{11}
S_{22}
E_{SR}
E_{DR}
Γ_{21}
E_{TR}
S_{12}
1
E_{XR}
(b)

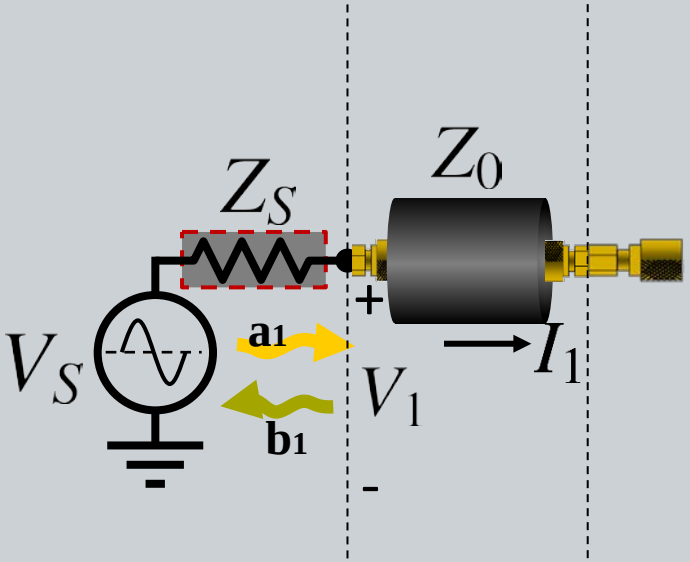
VNA Basics



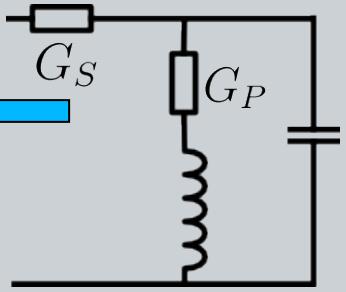
VNA Basics



VNA Basics



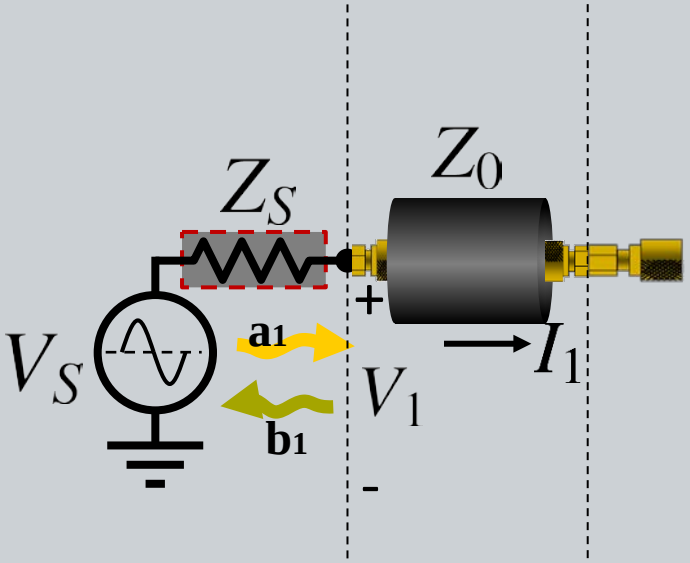
Calibration Std.



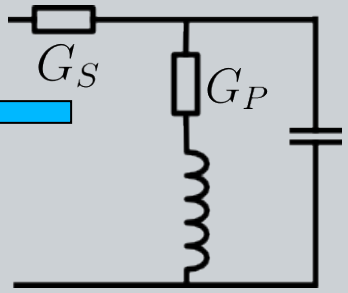
VNA model for Open, Short, Match

Calibration procedure use a polinomial fitting to obtain the constitutive parameters

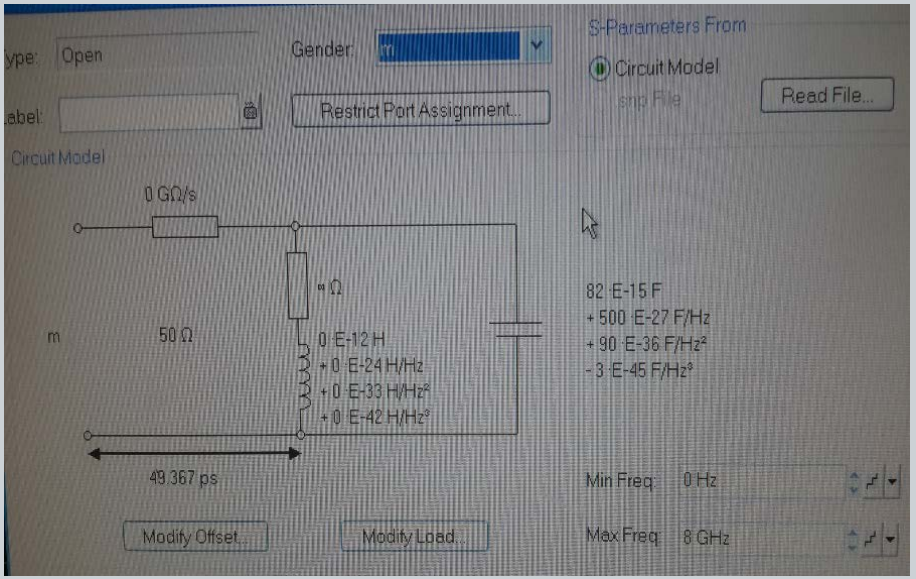
VNA Basics



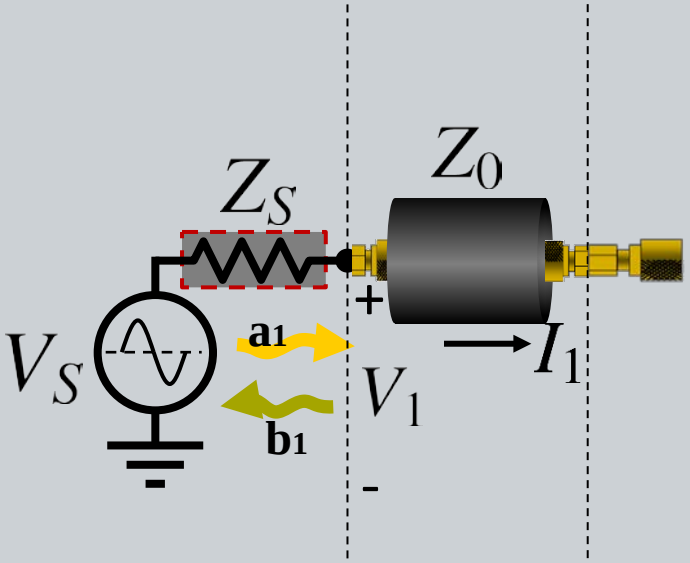
Calibration Std. **Open**



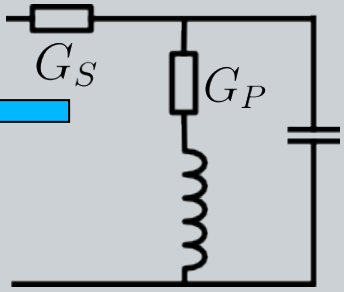
$$C = C_0 + C_1 f + C_2 f^2 + C_3 f^3$$



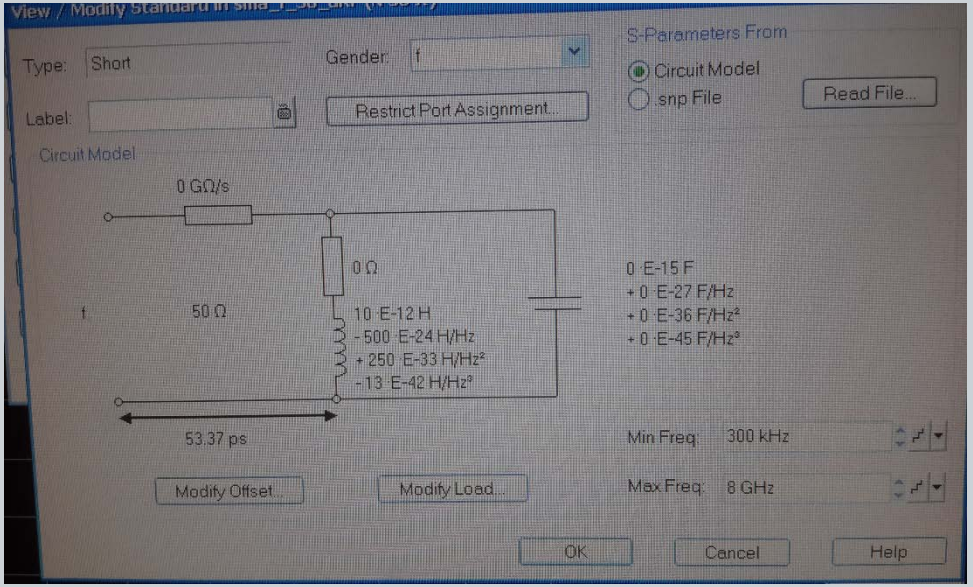
VNA Basics



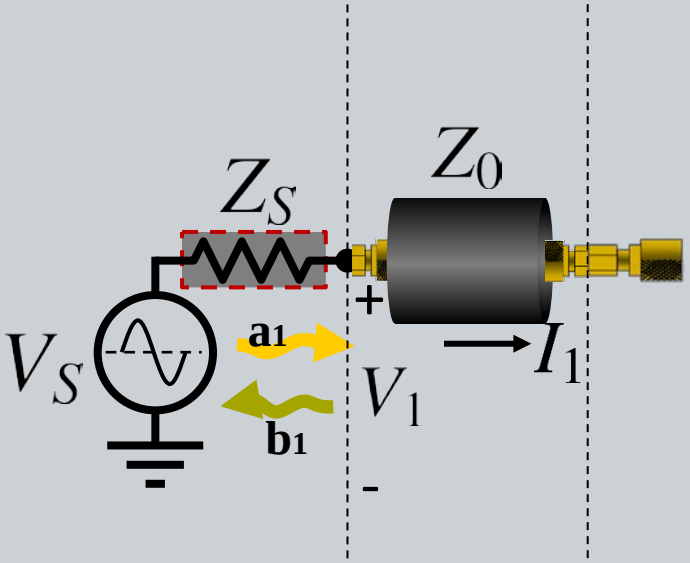
Calibration Std. **Short**



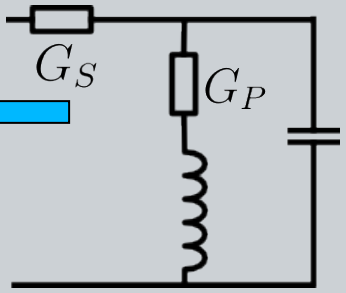
$$L = L_0 + L_1 f + L_2 f^2 + L_3 f^3$$

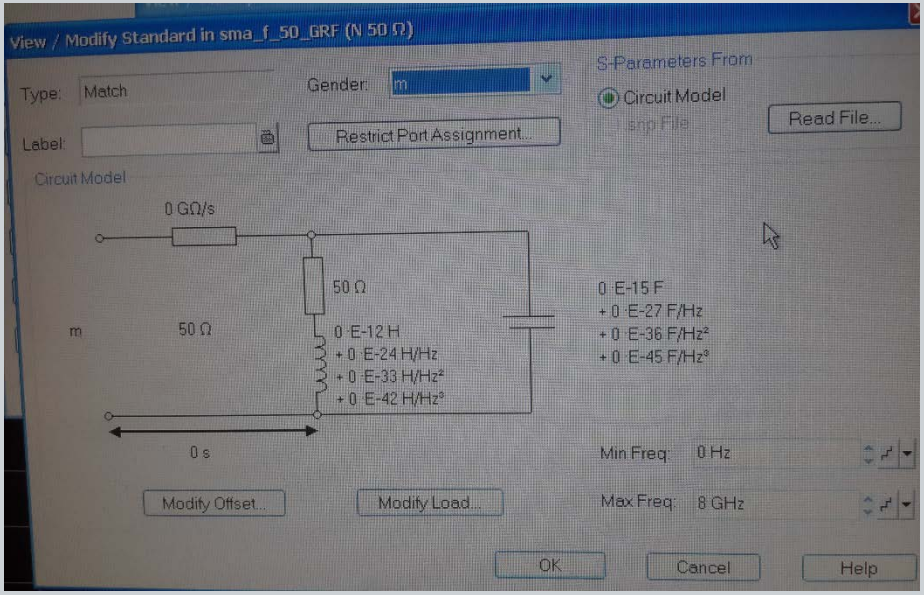


VNA Basics

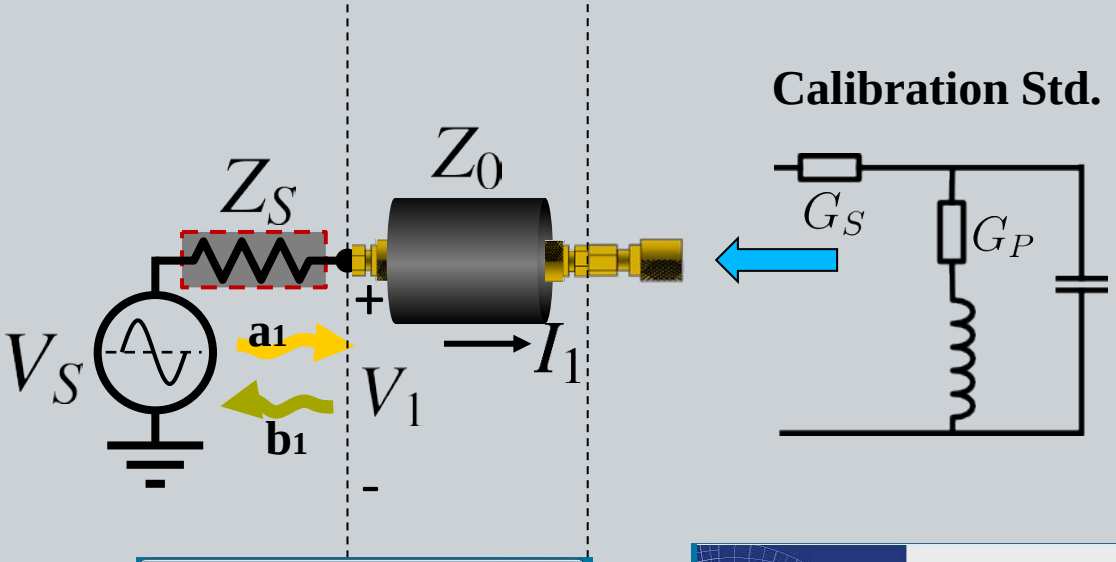


Calibration Std. **Match**

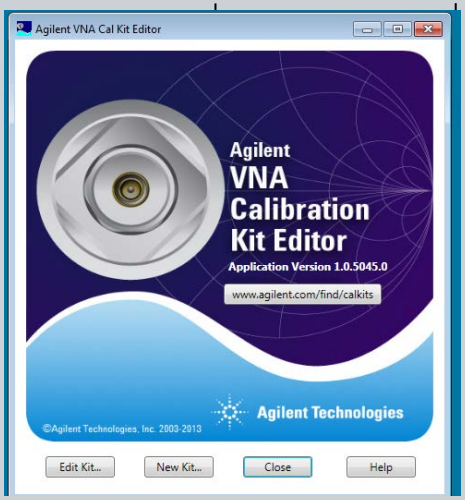


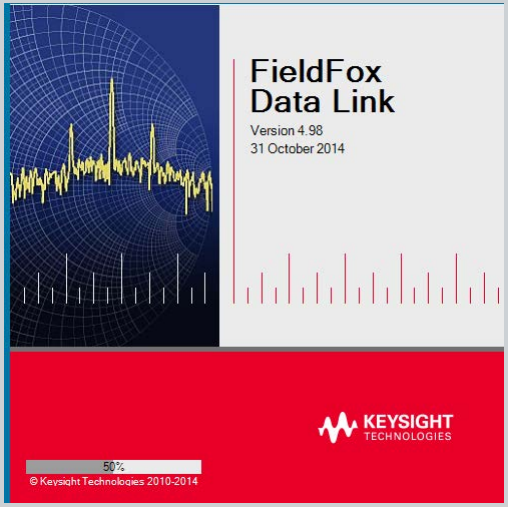


VNA Basics

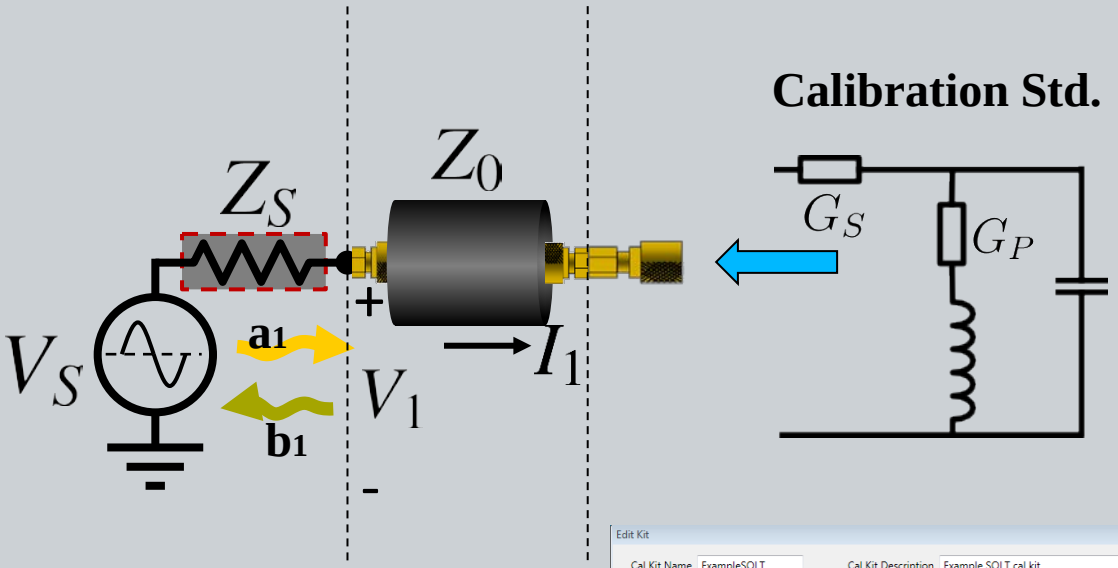


Calibration Std.

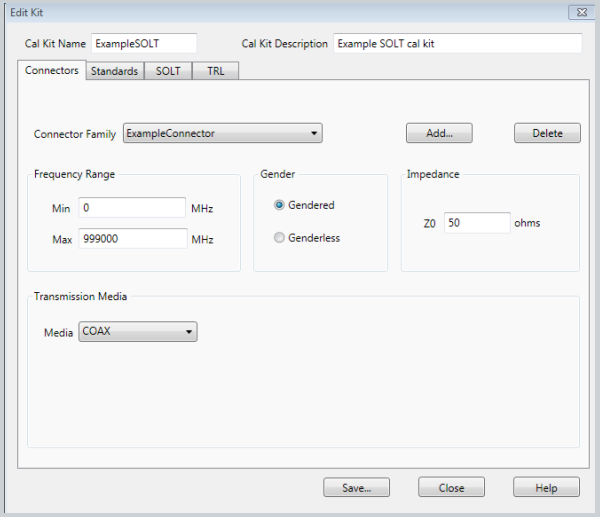




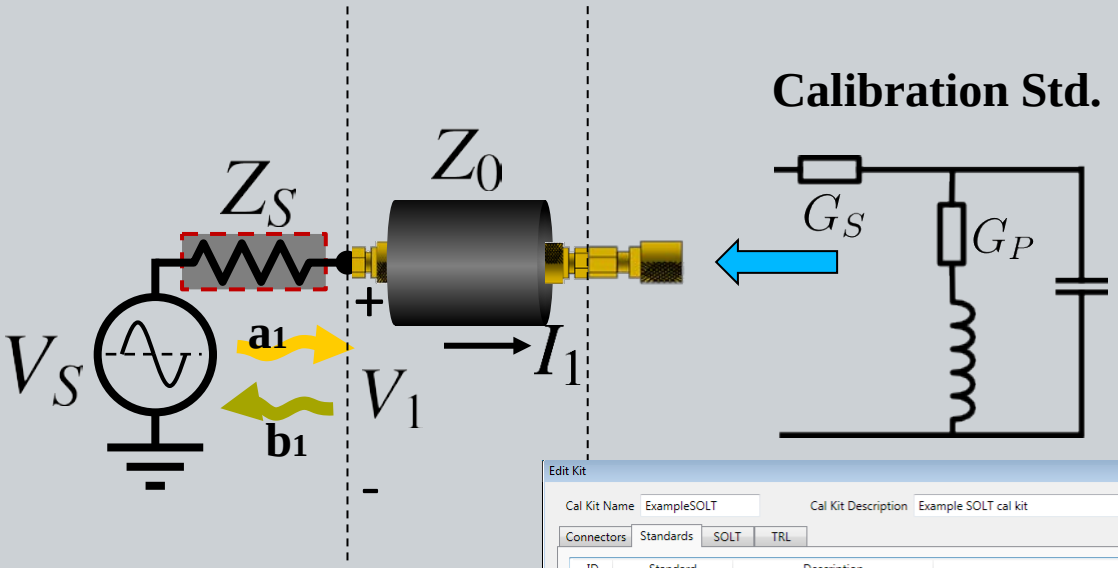
VNA Basics



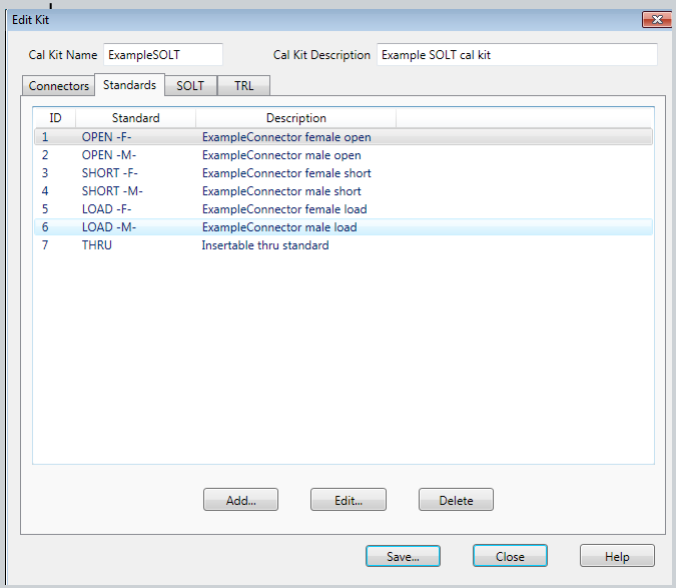
Calibration Std.



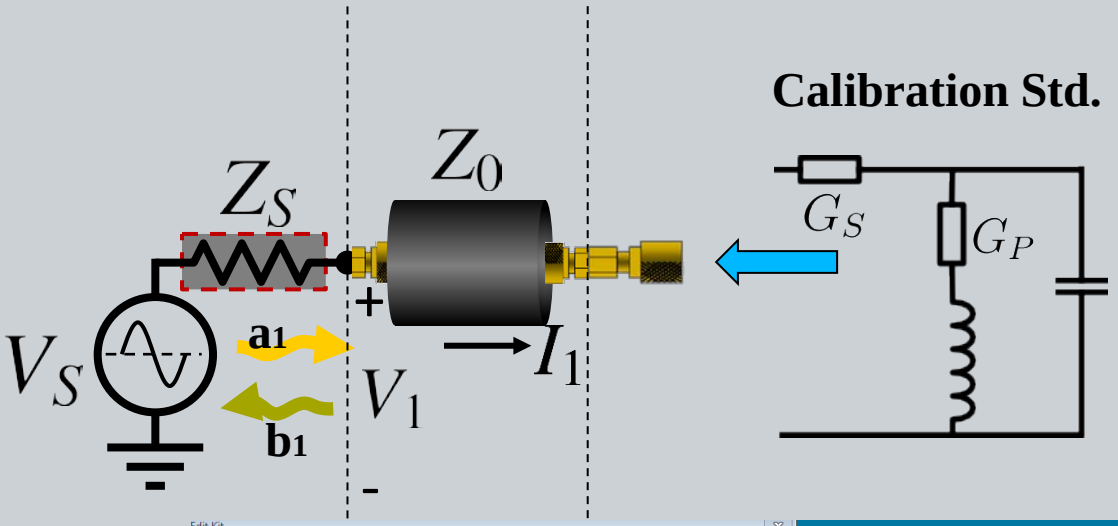
VNA Basics



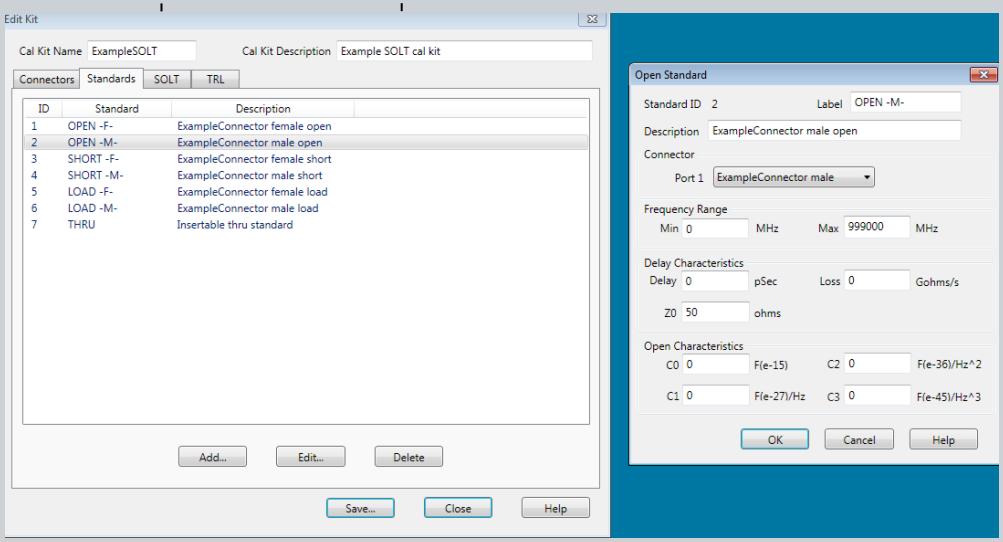
Calibration Std.



VNA Basics



Calibration Std.



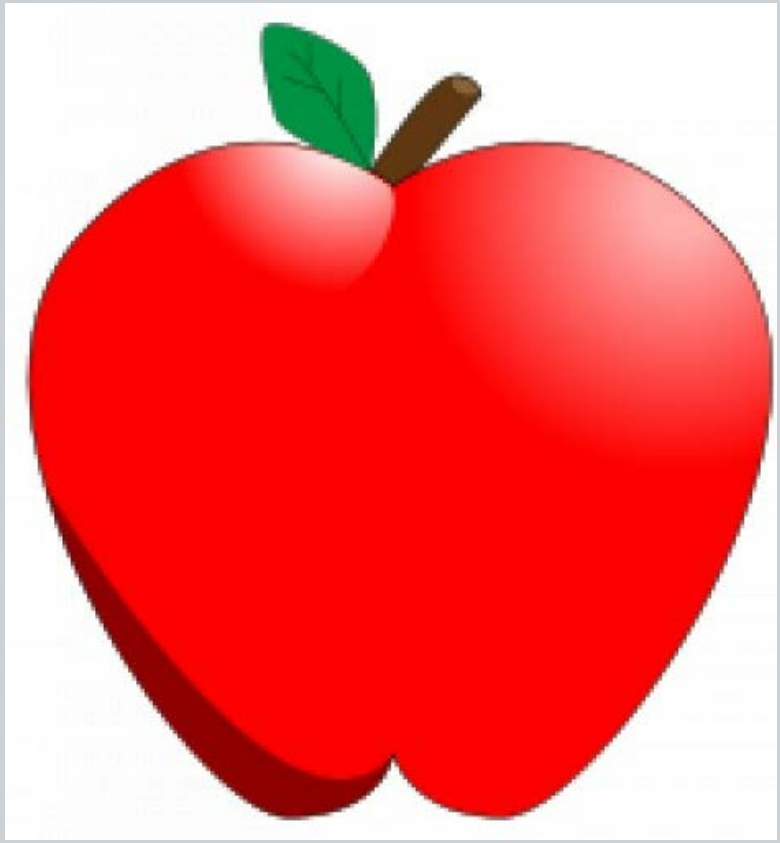
Obrigado
Galera!!!

¡¡¡ Gracias a todos!!!

Germán Andrés Álvarez Botero

galvarezbotero@gmail.com

UNIVERSIDADE FEDERAL
DE SANTA CATARINA



% **Código Mathematica**

```
ParametricPlot3D[{(1 + Cos[v]) Cos[u] + 0.085 Cos[5 u] + (0.994 v/p)^100,
(1 + Cos[v]) Sin[u]6 Sin[v] + 2 Cos[v] - 0.7 Log[1 - v/p]}, {u, -p, Pi}, {v, -p, Pi},
Mesh -> True, BoxRatios -> 1, PlotStyle -> {Green, Specularity[Yellow, 10]}]
```