Clicker lecture 2 of Topic 3: network analysis of microwave circuits

Feb 14, 2019

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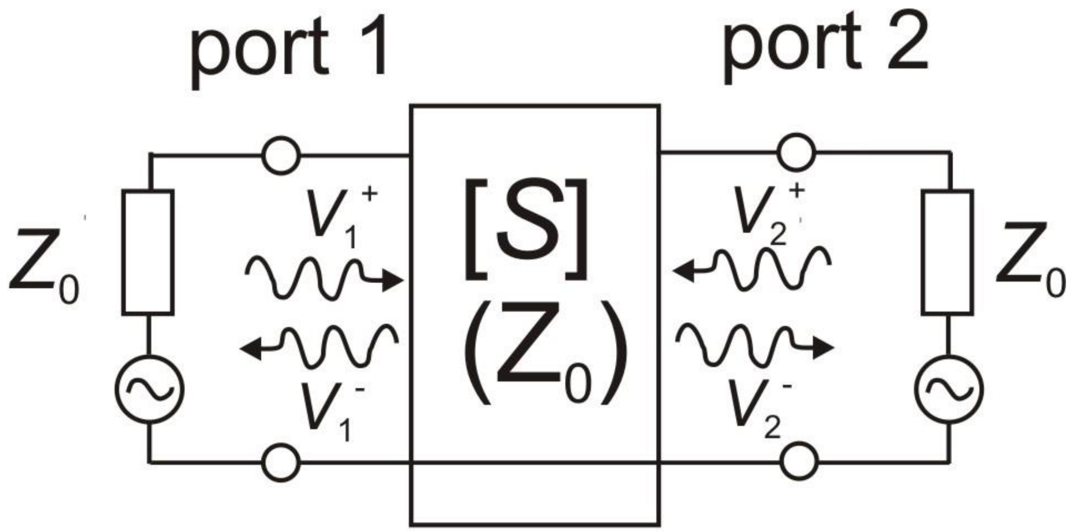
Today's topic is the *scattering parameters*, S-parameters



V_1^+ = voltage wave **in** to port 1

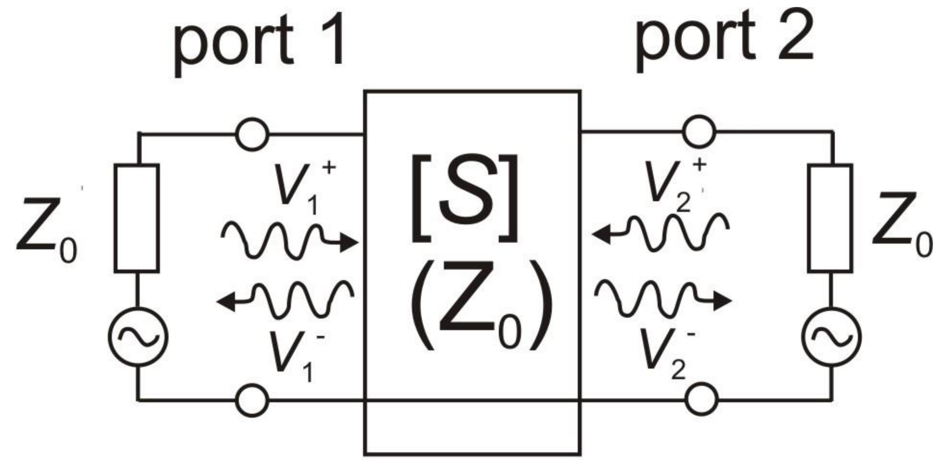
V_1^- = voltage wave **out** from port 1

$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

Q1: Which of the alternatives (1-6) is/are **false**?

Choose one or more!

1. When S-parameters are defined, all the ports are terminated with a reference impedance (often Z_0=50 Ω).
2. The S-parameters are **harder** to measure than, for instance, Z-parameters at the microwave frequencies.
3. S-parameters are generally frequency-dependent
4. S-parameters of passive circuits (excluding circuits with ferrites) are reciprocal – i.e., $S_{nm} = S_{mn}$, m≠n.
5. Power **in** to port 1 is $\frac{\left|V_1^+\right|^2}{2Z_0}$
6. I don't know



V_1^+ = voltage wave **in** to port 1

V_1^- = voltage wave **out** from port 1

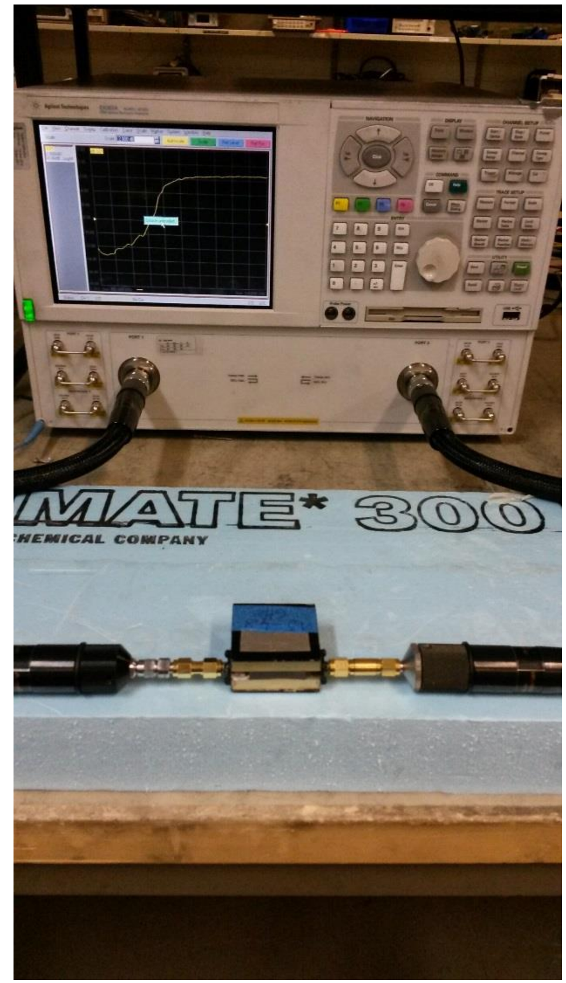
$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

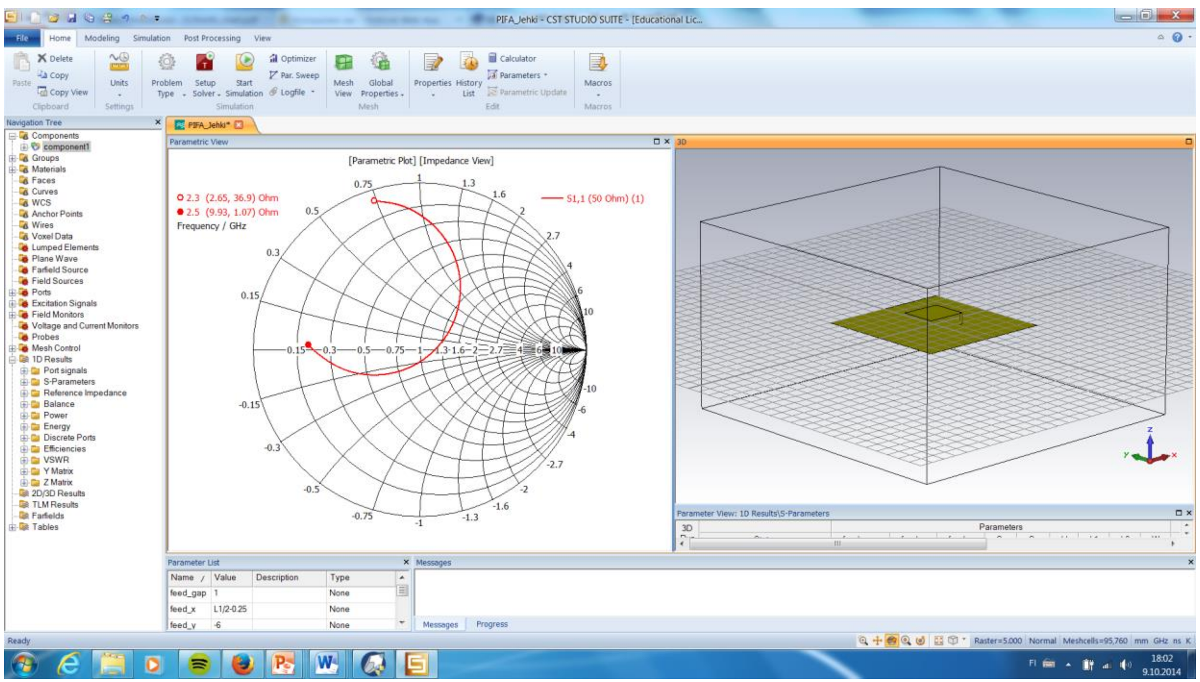
S-parameters

The importance of the S-parameters is that the ports can be **terminated with a matched impedance** (50 ohms) and then the S-parameters can be **measured** with a vector network analyser (VNA) or **simulated** with an electromagnetic or circuit simulator as a function of frequency.

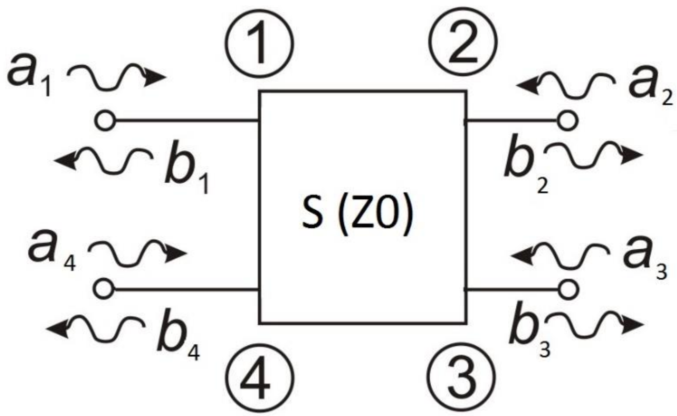
Vector network analyzer measurement



Electromagnetic simulation (CST Microwave Studio)



Q2: Port 1 of a four port is fed with a signal voltage $\boldsymbol{a_1}$ **= 1 mV**. Which of the statements is **true**.

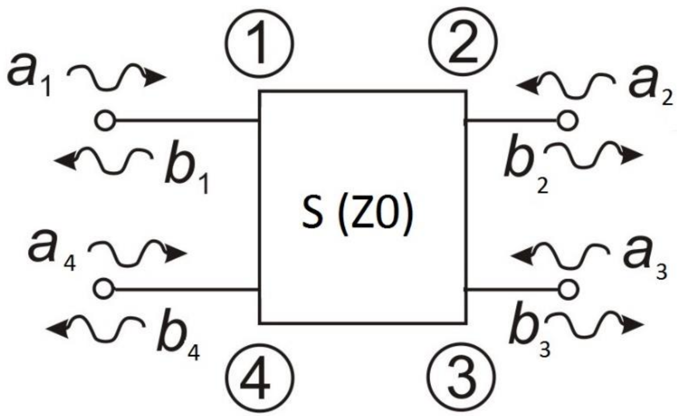


$$[S]=\begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & -1 & 0 \\ 0 & -1 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{bmatrix}.$$

a_n = voltage wave **in** to Port n, b_n = voltage wave **out** from Port n.

1. The reflected voltage from port 1 is b_1 = +1/2 mV.
2. The outcoming voltages b_2 and b_4 from ports 2 and 4 have a 180 degrees phase difference.
3. A half of the power fed in port 1 comes out from port 4
4. Isolation between ports 1 and 3 is very high
5. None of above
6. I don't know

Q3: Port 1 of a four port is fed with a signal voltage $\boldsymbol{a_1}$ = 1 mV. Which of the statements **false**.

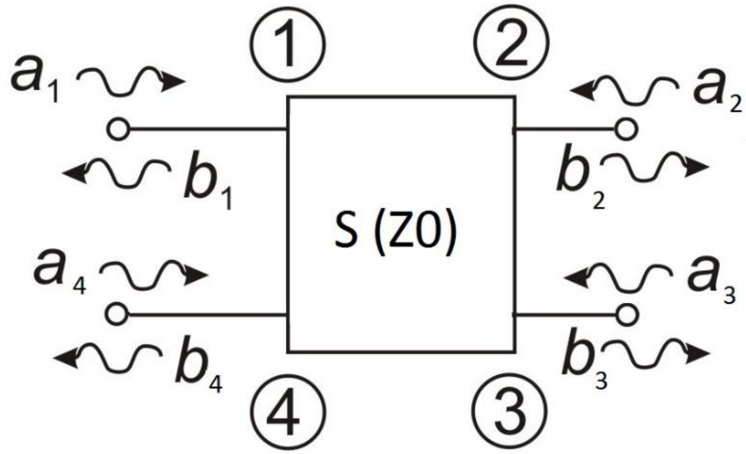


$$[S]=\begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & -1 & 0 \\ 0 & -1 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{bmatrix}.$$

a_n = voltage wave **in** to Port n, b_n = voltage wave **out** from Port n.

1. The four port is lossless.
2. The four port is fully matched.
3. The four port is reciprocal.
4. The four port might consist of passive components.
5. None of above
6. I don't know

Q4: Which value of the parameter ***a*** can make the S-parameter matrix that of a **passive** and **lossless** circuit?

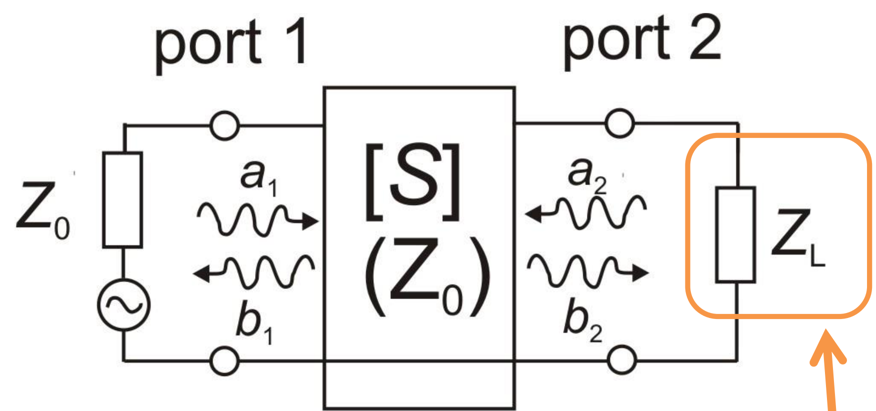


$$[S] = a \cdot \begin{bmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & -1 & 0 \\ 0 & -1 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{bmatrix}$$

1. $a = \frac{1}{2}$
2. $a = \frac{1}{\sqrt{2}}$
3. $a = 1$
4. $a = \sqrt{2}$
5. None of above
6. I don't know

Q5: Port 2 is terminated with a load impedance $\boldsymbol{Z_L} \neq \boldsymbol{Z_0}$. Conclude, which of the is the reflection coefficient ρ_{in} in port 1 is **impossible**?

1. $\rho_{in} = 0$
2. $\rho_{in} = \rho_L$
3. $\rho_{in} = S_{11}$
4. None of above
5. I don't know



a_1 = voltage wave **in** to port 1

b_1 = voltage wave **out** from port 1

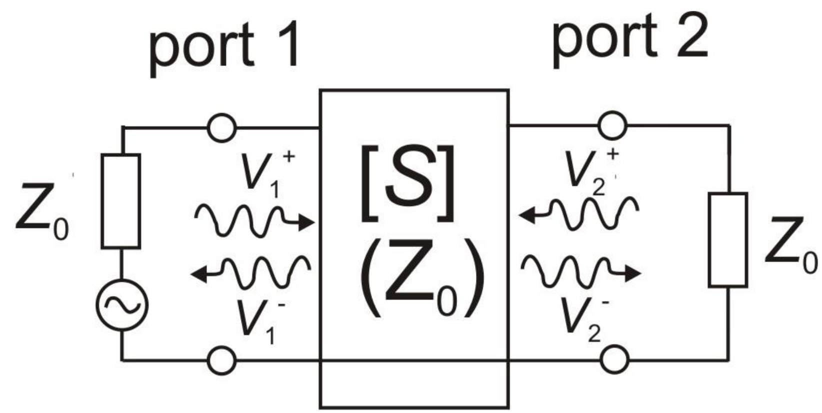
$$\rho_L = \frac{Z_L - Z_0}{Z_L + Z_0} \neq 0 \qquad S_{ij} \neq 0$$

S-parameters are physical values of a **passive** and **reciprocal** circuit.

Q6: What is the numeric value (dB) of **gain** of the amplifier?

$$S = \begin{bmatrix} 0.10\angle -137^o & 0.010\angle 27^o \\ 4.0\angle -36{,}18^o & 0.10\angle -88^o \end{bmatrix}$$

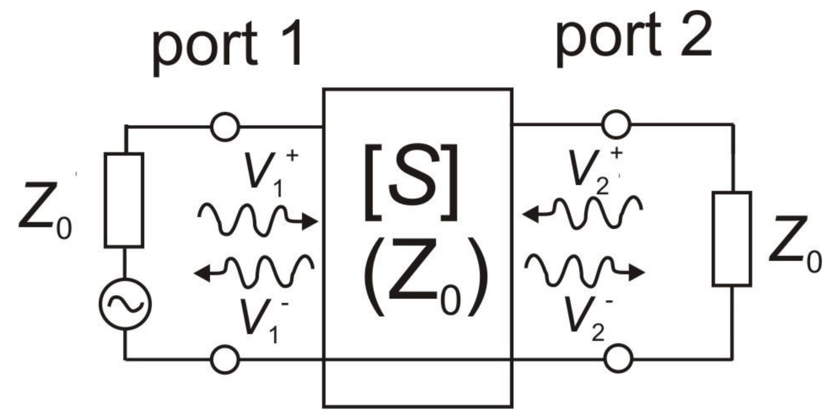
$\log_{10} 0.1 = -1$ $\log_{10} 0.01 = -2$
$\log_{10} 4 \approx 0.6$



1. 3 dB
2. 6 dB
3. 10 dB
4. 12 dB
5. 20 dB
6. I don't know

Q7: What is the numeric value (dB) of the **reflection coefficient in port 1**?

$$S = \begin{bmatrix} 0.10\angle -137^o & 0.010\angle 27^o \\ 4.0\angle -36{,}18^o & 0.10\angle -88^o \end{bmatrix}$$



$\log_{10} 0.1 = -1$ $\log_{10} 0.01 = -2$
$\log_{10} 4 \approx 0.6$

1. -3 dB
2. -6 dB
3. -10 dB
4. -12 dB
5. -20 dB
6. I don't know