



EMIMEO : E(rasmus) Mundus on Innovative Microwave Electronics and Optics Master

Foundations of Electromagnetic Wave Propagation – 2nd part

Contributors:

Olivier Tantot
Guillaume Neveux
Serge Verdeyme



UNIVERSITÀ
DEGLI STUDI
DI BRESCIA



Universidad del País Vasco
Euskal Herriko Unibertsitatea
The University of the Basque Country



UNIVERSITATEA TEHNICĂ
DIN CLUJ-NAPOCA

Foundations of electromagnetic wave propagation

November 2021 - 1 -

Copyright notice : This material can be freely used within the E.M.I.M.E.O. Erasmus Mundus consortium. Explicit authorisation of the authors is required for its use outside this E.M.I.M.E.O. consortium. This learning Programme has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



Chapters:

0. Microwave domain

1. S-parameters and transmission line

- Microwave signals - time and frequency domains
- Description of microwave devices by scattering parameters
- Exercises on the parameters S
- Description of microwave devices by chain matrix

2. Theory of transmission lines

3. Smith Chart and impedance matching

- Introduction, uses and principles
- Movement along the line
- Different methods for impedance matching
- Matching by a stub
- Matching by double stubs

Foundations of electromagnetic wave propagation

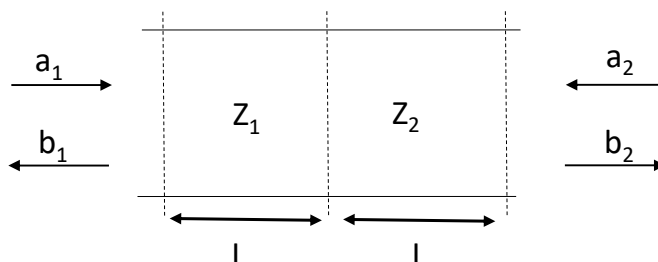
November 2021 - 2 -

Copyright notice : This material can be freely used within the E.M.I.M.E.O. Erasmus Mundus consortium. Explicit authorisation of the authors is required for its use outside this E.M.I.M.E.O. consortium. This learning Programme has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

1. S-parameters and transmission line

16. S matrix of a series impedance

Exercise #3 : S matrix of impedance step



the matrix S is normalized with respect to:

- Z_1 at port 1
- Z_2 at port 2

From Kirchoff's and Ohm's laws and the expressions (1) of slide 1-4, give the S matrix of this diagram

Foundations of electromagnetic wave propagation

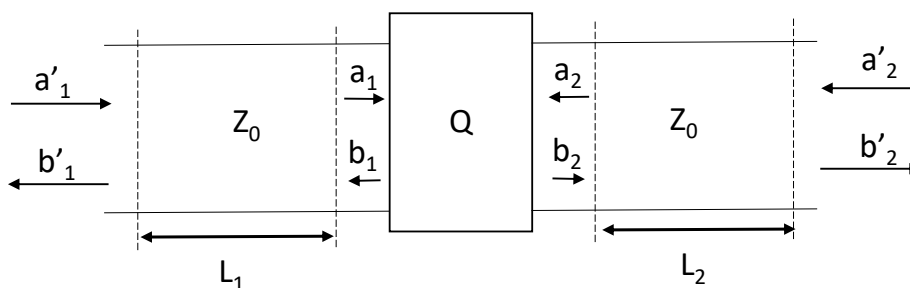
November 2021 - 3 -

Copyright notice : This material can be freely used within the E.M.I.M.E.O. Erasmus Mundus consortium. Explicit authorisation of the authors is required for its use outside this E.M.I.M.E.O. consortium. This learning Programme has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

1. S-parameters and transmission line

17. S matrix of a series impedance

Exercise #4 : S matrix of a quadripole connected to 2 transmission line



The S matrix of the quadripole Q, normalized with respect to Z_0 , is assumed to be known. The connection lines are assumed to be lossless, with characteristic impedance Z_0

Give the S matrix of this diagram

Foundations of electromagnetic wave propagation

November 2021 - 4 -

Copyright notice : This material can be freely used within the E.M.I.M.E.O. Erasmus Mundus consortium. Explicit authorisation of the authors is required for its use outside this E.M.I.M.E.O. consortium. This learning Programme has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Chapters:

0. Microwave domain

1. S-parameters and transmission line

- Microwave signals - time and frequency domains
- Description of microwave devices by scattering parameters
- Exercises on the parameters S
- Description of microwave devices by chain matrix

2. Theory of transmission lines

3. Smith Chart and impedance matching

- Introduction, uses and principles
- Movement along the line
- Different methods for impedance matching
- Matching by a stub
- Matching by double stubs

1. S-parameters and transmission line

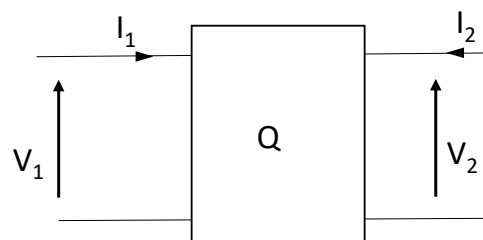
1. Description of microwave devices by chain matrix

Unfortunately, if quadripoles are cascaded, the S matrices of the quadripoles cannot be chained to obtain the S matrix of the set.

To remove this defect, the chain matrix has been developed:

with

$$\begin{aligned} V_1 &= A \cdot V_2 - B \cdot I_2 \\ I_1 &= C \cdot V_2 - D \cdot I_2 \end{aligned}$$



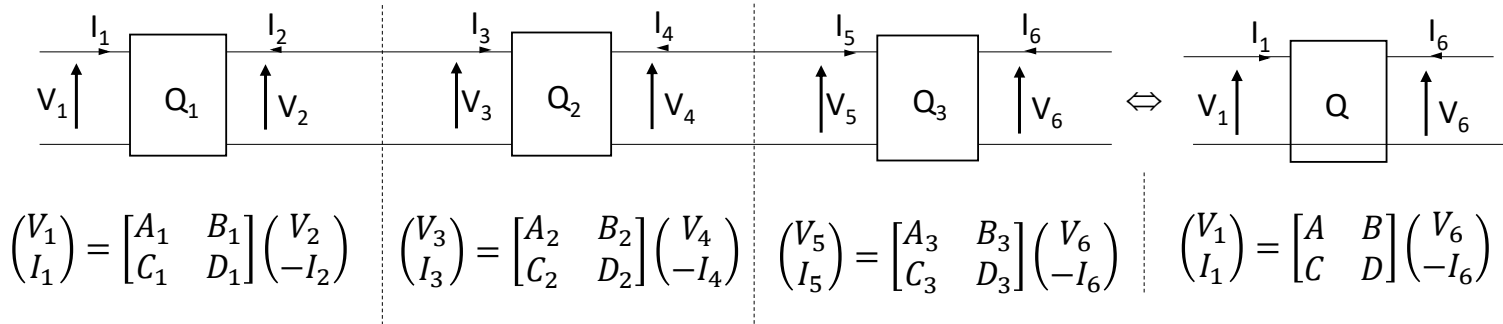
And the relationships between coefficients are : $AD - BC = 1$

1. S-parameters and transmission line

2. Description of microwave devices by chain matrix

and input impedance of the quadripole loaded by Z_L : $Z_{in} = \frac{A \cdot Z_L + B}{C \cdot Z_L + D}$

Cascaded quadripoles :



thus
$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} A_3 & B_3 \\ C_3 & D_3 \end{bmatrix} \begin{pmatrix} V_6 \\ -I_6 \end{pmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{pmatrix} V_6 \\ -I_6 \end{pmatrix}$$

References:

- [1] David M. Pozar, Microwave Engineering, Third Edition, John Wiley & Sons Inc.; (ISBN 0-471-17096-8)
- [2] Jia-Sheng Hong, M. J. Lancaster, Microstrip Filters for RF/Microwave Applications, John Wiley & Sons Inc. (ISBN: 0-471-38877-7)
- [3] G. Ghione, M. Pirola, Microwave Electronics, Cambridge University Press (ISBN 978-1-107-17027-8)
- [4] Richard Collier, Transmission Lines, Cambridge University Press (ISBN 978-1-107-02600-1)
- [5] V. Teppati, A. Ferrero, M. Sayed, Modern RF and Microwave Measurement Techniques, Cambridge University Press (ISBN 978-1-107-03641-3)
- [6] Y. Kusama and R. Isozaki, "Compact and Broadband Microstrip Band-Stop Filters with Single Rectangular Stubs", Applied Sciences, vol. 9, n0 248, 2019,