

# RF engineering basic concepts: S-parameters

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## Abstract

The concept of describing RF circuits in terms of waves is discussed and the S-matrix and related matrices are defined. The signal flow graph (SFG) is introduced as a graphical means to visualize how waves propagate in an RF network. The properties of the most relevant passive RF devices (hybrids, couplers, non-reciprocal elements, etc.) are delineated and the corresponding S-parameters are given. For microwave integrated circuits (MICs) planar transmission lines such as the microstrip line have become very important.

## 1 S-parameters

The abbreviation S has been derived from the word *scattering*. For high frequencies, it is convenient to describe a given network in terms of waves rather than voltages or currents. This permits an easier definition of reference planes. For practical reasons, the description in terms of in- and outgoing waves has been introduced. Now, a 4-pole network becomes a 2-port and a  $2n$ -pole becomes an  $n$ -port. In the case of an odd pole number (e.g., 3-pole), a common reference point may be chosen, attributing one pole equally to two ports. Then a 3-pole is converted into a  $(3+1)$  pole corresponding to a 2-port. As a general conversion rule, for an odd pole number one more pole is added.

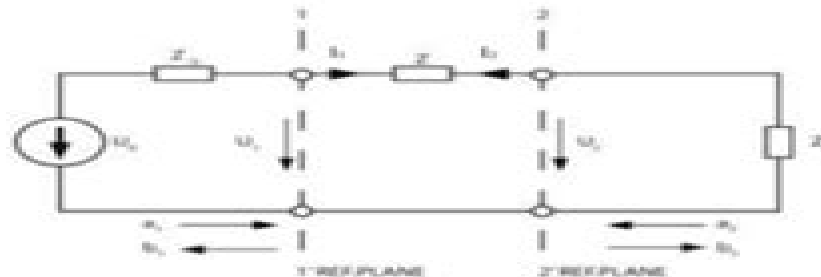


Fig. 1: Example for a 2-port network: a series impedance  $Z$

Let us start by considering a simple 2-port network consisting of a single impedance  $Z$  connected in series (Fig. 1). The generator and load impedances are  $Z_0$  and  $Z_L$ , respectively. If  $Z = 0$  and  $Z_L = Z_0$  (for real  $Z_0$ ) we have a matched load, i.e., maximum available power goes into the load and  $U_1 = U_2 = U_G/2$ . Note that all the voltages and currents are peak values. The lines connecting the different elements are supposed to have zero electrical length. Connections with a finite electrical length are drawn as double lines or as heavy lines. Now we would like to relate  $U_0$ ,  $U_1$  and  $U_2$  to  $a$  and  $b$ .

# Rf Engineering Basic Concepts S Parameters Cern

**Julia Schneider**



## **Rf Engineering Basic Concepts S Parameters Cern:**

*Advances in Microwave Engineering* Ankan Bhattacharya, Bappaditya Roy, Arnab De, Ujjal Chakraborty, Anup Kumar Bhattacharjee, 2023-11-21 This text showcases recent advancements in the field of microwave engineering starting from the use of innovative materials to the latest microwave applications. It also highlights safety guidelines for exposure to microwave and radio frequency energy. The book provides information on measuring circuit parameters and dielectric parameters. Explains microwave antennas, microwave communication, microwave propagation, microwave devices and circuits in detail. Covers microwave measurement techniques, radiation hazards, space communication and safety measures. Focuses on advanced computing technologies, wireless communication and fiber optics. Presents scattering matrix and microwave passive components and devices such as phase shifters and power dividers. Showcases the importance of space communication, radio astronomy, microwave material processing and advanced computing technologies. The text provides a comprehensive study of the foundations of microwave heating and its interactions with materials for various applications. It also addresses applications of microwave devices and technologies in diverse areas including computational electromagnetics, remote sensing, transmission lines, radiation hazards and safety measures. It emphasizes the impact of resonances on microwave power absorption and the effect of nonuniformity on heating rates. The text is primarily written for senior undergraduate students, graduate students and academic researchers in the fields of electrical engineering, electronics and communication engineering, computer engineering and materials science.

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principles     **Handbook Of Accelerator Physics And Engineering (Third Edition)** Alexander Wu Chao, Maury Tigner, Hans Weise, Frank Zimmermann, 2023-02-02 Edited by internationally recognized authorities in the field this expanded and updated new edition of the bestselling Handbook containing many new articles is aimed at the design and operation of modern particle accelerators It is intended as a vade mecum for professional engineers and physicists engaged in these subjects With a collection of more than 2000 equations 300 illustrations and 500 graphs and tables here one will find in addition to common formulae of previous compilations hard to find specialized formulae recipes and material data pooled from the lifetime experience of many of the world's most able practitioners of the art and science of accelerators The seven chapters include both theoretical and practical matters as well as an extensive glossary of accelerator types Chapters on beam dynamics and electromagnetic and nuclear interactions deal with linear and nonlinear single particle and collective effects including spin motion beam environment beam-beam beam-electron beam-ion and intrabeam interactions The impedance concept and related calculations are dealt with at length as are the instabilities due to the various interactions mentioned A chapter on operational considerations including discussions on the assessment and correction of orbit and optics errors realtime feedbacks generation of short photon pulses bunch compression phase space exchange tuning of normal and superconducting linacs energy recovery linacs free electron lasers cryogenic vacuum systems steady state microbunching cooling space charge compensation brightness of light sources collider luminosity optimization and collision schemes machine learning multiple frequency rf systems FEL seeding ultrafast electron diffraction and Gamma Factory Chapters on mechanical and electrical considerations present material data and important aspects of component design including heat transfer and refrigeration Hardware systems for particle sources feedback systems confinement including undulators and acceleration both normal and superconducting receive detailed treatment in a sub systems chapter beam measurement and apparatus being treated therein as well A detailed name and subject index is provided together with reliable references to the literature where the most detailed information available on all subjects treated can be found

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