

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.

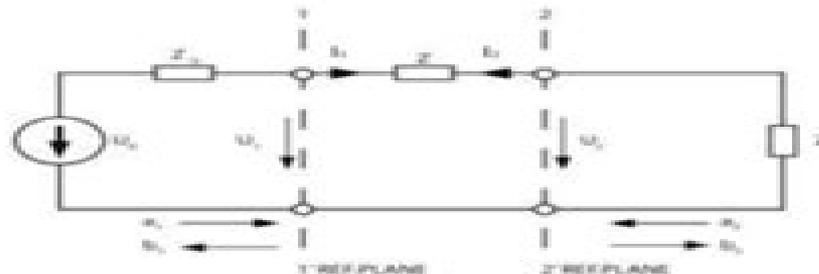


Fig. 1: Example for a 2-port network: a series impedance Z

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_G and Z_L , respectively. If $Z = 0$ and $Z_G = Z_L$ (for real Z_G) 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_G , U_1 and U_2 to a and b .

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