



FIGURE 4.13 Equivalent circuits for a reciprocal two-port network. (a) T equivalent. (b) π equivalent.

A nonreciprocal network cannot be represented by a passive equivalent circuit using reciprocal elements.

If the network is lossless, which is a good approximation for many practical two-port junctions, some simplifications can be made in the equivalent circuit. As was shown in Section 4.2, the impedance or admittance matrix elements are purely imaginary for a lossless network. This reduces the degrees of freedom for such a network to three, and implies that the T and π equivalent circuits of Figure 4.13 can be constructed from purely reactive elements.

4.5

SIGNAL FLOW GRAPHS

We have seen how transmitted and reflected waves can be represented by scattering parameters, and how the interconnection of sources, networks, and loads can be treated with various matrix representations. In this section we discuss the *signal flow graph*, which is an additional technique that is very useful for the analysis of microwave networks in terms of transmitted and reflected waves. We first discuss the features and the construction of the flow graph itself, and then present a technique for the reduction, or solution, of the flow graph.

The primary components of a signal flow graph are nodes and branches:

- **Nodes:** Each port i of a microwave network has two nodes, a_i and b_i . Node a_i is identified with a wave entering port i , while node b_i is identified with a wave reflected from port i . The voltage at a node is equal to the sum of all signals entering that node.
- **Branches:** A branch is a directed path between two nodes representing signal flow from one node to another. Every branch has an associated scattering parameter or reflection coefficient.

At this point it is useful to consider the flow graph of an arbitrary two-port network, as shown in Figure 4.14. Figure 4.14a shows a two-port network with incident and reflected waves at each port, and Figure 4.14b shows the corresponding signal flow graph representation. The flow graph gives an intuitive graphical illustration of the network behavior.

For example, a wave of amplitude a_1 incident at port 1 is split, with part going through S_{11} and out port 1 as a reflected wave, and part transmitted through S_{21} to node b_2 .