## <u>Reciprocal and</u> <u>Lossless Networks</u>

We can **classify** multi-port devices or networks as either **lossless** or lossy; **reciprocal** or non-reciprocal. Let's look at each classification individually:

## Lossless

A lossless network or device is simply one that cannot absorb power. This does not mean that the delivered power at every port is zero; rather, it means the total power flowing into the device must equal the total power exiting the device.

A lossless device exhibits an impedance matrix with an interesting **property**. Perhaps not surprisingly, we find for a lossless device that the **elements** of its impedance matrix will be **purely reactive**:

$$Re\{Z_{mn}\}=0$$
 for a lossless device.

If the device is lossy, then the elements of the impedance matrix must have **at least** one element with a real (i.e., resistive) component. Moreover, we similarly find that if the elements of an **admittance** matrix are **all** purely imaginary (i.e.,  $Re\{Y_{mn}\} = 0$ ), then the device is lossless.

## Reciprocal

Generally speaking, most **passive**, **linear** microwave components will turn out to be **reciprocal**—regardless of whether the designer **intended** it to be or not!

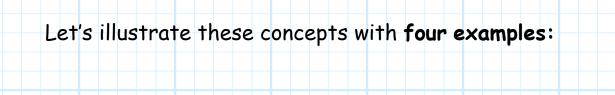
Reciprocity is basically a "natural" effect of using simple linear materials such as **dielectrics** and **conductors**. It results from a characteristic in **electromagnetics** called "reciprocity"—a characteristic that is difficult to **prevent**!

But reciprocity is a tremendously important characteristic, as it greatly **simplifies** an impedance or admittance matrix!

Specifically, we find that a reciprocal device will result in a symmetric impedance and admittance matrix, meaning that:

$$Z_{mn} = Z_{nm}$$
  $Y_{mn} = Y_{nm}$  for reciprocal devices

For **example**, we find for a reciprocal device that  $Z_{23} = Z_{32}$ , and  $Y_{21} = Y_{12}$ . [; ;**?** 



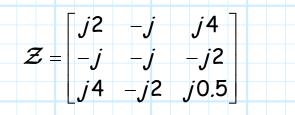
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$$\mathcal{Z} = \begin{bmatrix} j2 & 0.1 & j3 \\ -j & -1 & 1 \\ 4 & -2 & 0.5 \end{bmatrix}$$
 Neither lossless nor reciprocal.

$$\mathcal{Z} = \begin{bmatrix} j2 & j0.1 & j3 \\ -j & -j1 & j1 \\ j4 & -j2 & j0.5 \end{bmatrix}$$
 Lossless, but not reciprocal

$$\mathcal{Z} = \begin{bmatrix} j2 & -j & 4 \\ -j & -1 & -j2 \\ 4 & -j2 & j0.5 \end{bmatrix}$$
 **Reciprocal**, but not lossless.



Both reciprocal and lossless.