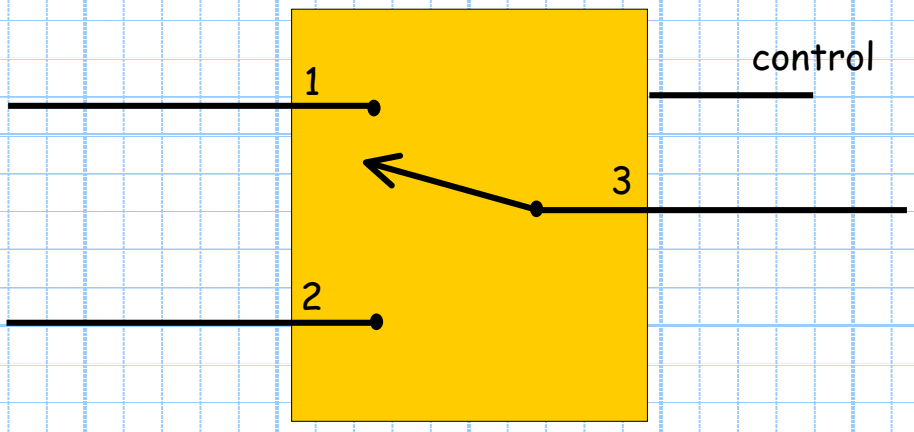
Microwave Switches

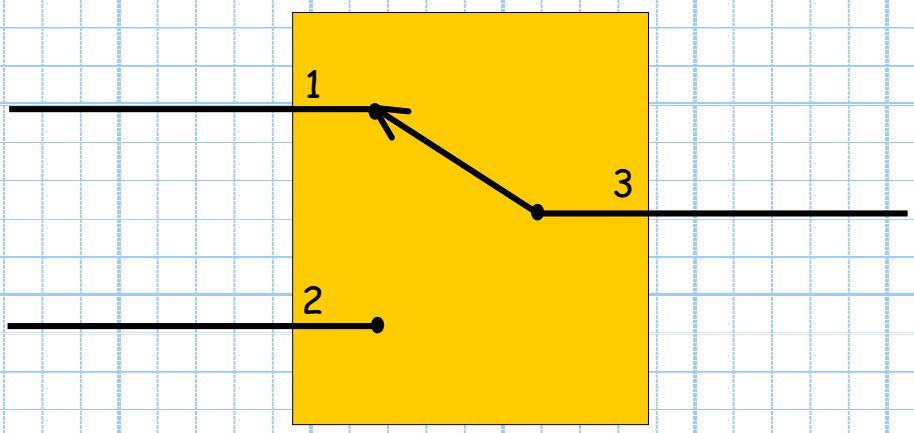
Consider an **ideal** microwave SPDT **switch**.



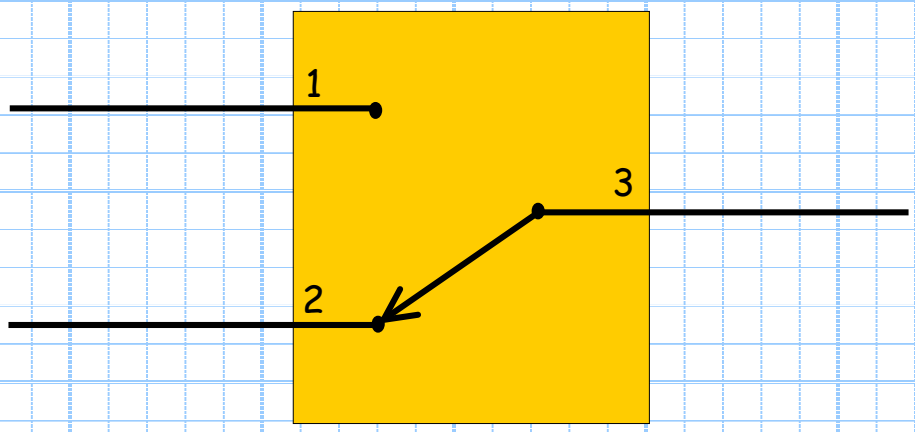
The **scattering matrix** will have one of two forms:

$$\bar{\bar{S}}_{13} = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix} \qquad \bar{\bar{S}}_{23} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

where $\bar{\bar{S}}_{13}$ describes the device when port 1 is **connected** to port 3:



and where $\bar{\bar{S}}_{23}$ describes the device when port 2 is **connected** to port 3:



These ideal switches are called matched, or **absorptive switches**, as ports 1 and 2 remain matched, even when **not connected**.

This is in contrast to a **reflective switch**, where the disconnected port will be perfectly reflective, i.e.,

$$\bar{\bar{S}}_{13} = \begin{bmatrix} 0 & 0 & 1 \\ 0 & e^{j\phi} & 0 \\ 1 & 0 & 0 \end{bmatrix} \qquad \bar{\bar{S}}_{23} = \begin{bmatrix} e^{j\phi} & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

where of course $\left|e^{j\phi}\right| = 1$.

Of course, just as with **all** ideal components, the ideal switch does **not** exist!

Using the fact that switches are **reciprocal** devices, we can write for $\bar{\bar{S}}_{13}$ for a non-ideal switch:

$$\bar{\bar{S}}_{13} = \begin{bmatrix} S_{11} & S_{21} & S_{31} \\ S_{21} & S_{22} & S_{32} \\ S_{31} & S_{32} & S_{33} \end{bmatrix}$$

We can therefore consider the following **parameters** for specifying switch performance.

Insertion Loss

$$IL = -10\log_{10}\left(\left|S_{31}\right|^2\right)$$

Insertion Loss indicates the loss encountered as a signal propagates **through** the switch. Ideally, this value is 0 dB. Typically, this value is around 1 dB.

Isolation

$$Isolation = -10\log_{10}\left(\left|S_{32}\right|^2\right)$$

Isolation is a measure of how much power "leaks" into the disconnected port. Ideally, this value would be very large—typical switch isolation is 30 – 50 dB.

Return Loss

$$Return\ Loss = -10\log_{10}\left(\left|S_{11}\right|^2\right)$$

Just as we have always defined it ! We of course want this value to very high (typical values are 20 to 40 dB). However, we find for reflective switches, this value can be nearly 0 dB for the disconnected port!