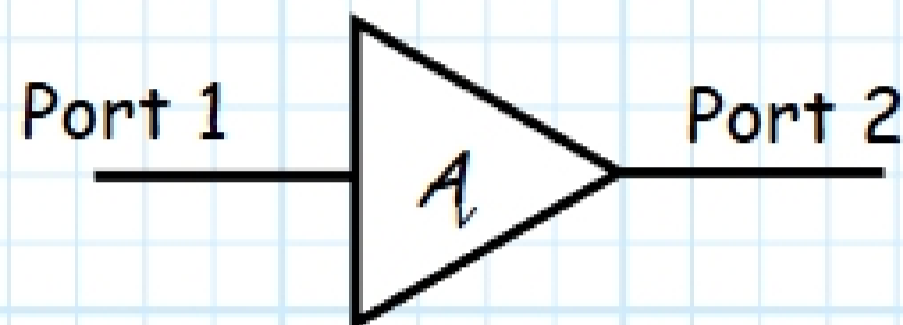


Amplifier Gain

Note that an amplifier is a **two-port** device.



As a result, we can describe an amplifier with a 2×2 **scattering matrix**:

$$\bar{\bar{S}}(\omega) = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix}$$

Q: What is the scattering matrix of an **ideal** amplifier??

A: Let's start with S_{11} and S_{22} .

To insure maximum power transfer, the input and output ports would ideally be matched:

$$S_{11} = S_{22} = 0$$

Now, let's look at scattering parameter S_{21} . We know that:

$$P_2^- = |S_{21}|^2 P_1^+$$

or, stated **another** way:

$$P_{out} = |S_{21}|^2 P_{in}$$

Therefore, we can **define** the amplifier **power gain** as:

$$G \doteq \frac{P_{out}}{P_{in}} = |S_{21}|^2$$

As the purpose of an amplifier is to boost the signal power, we can conclude that **ideally**:

$$|S_{21}| \gg 1$$

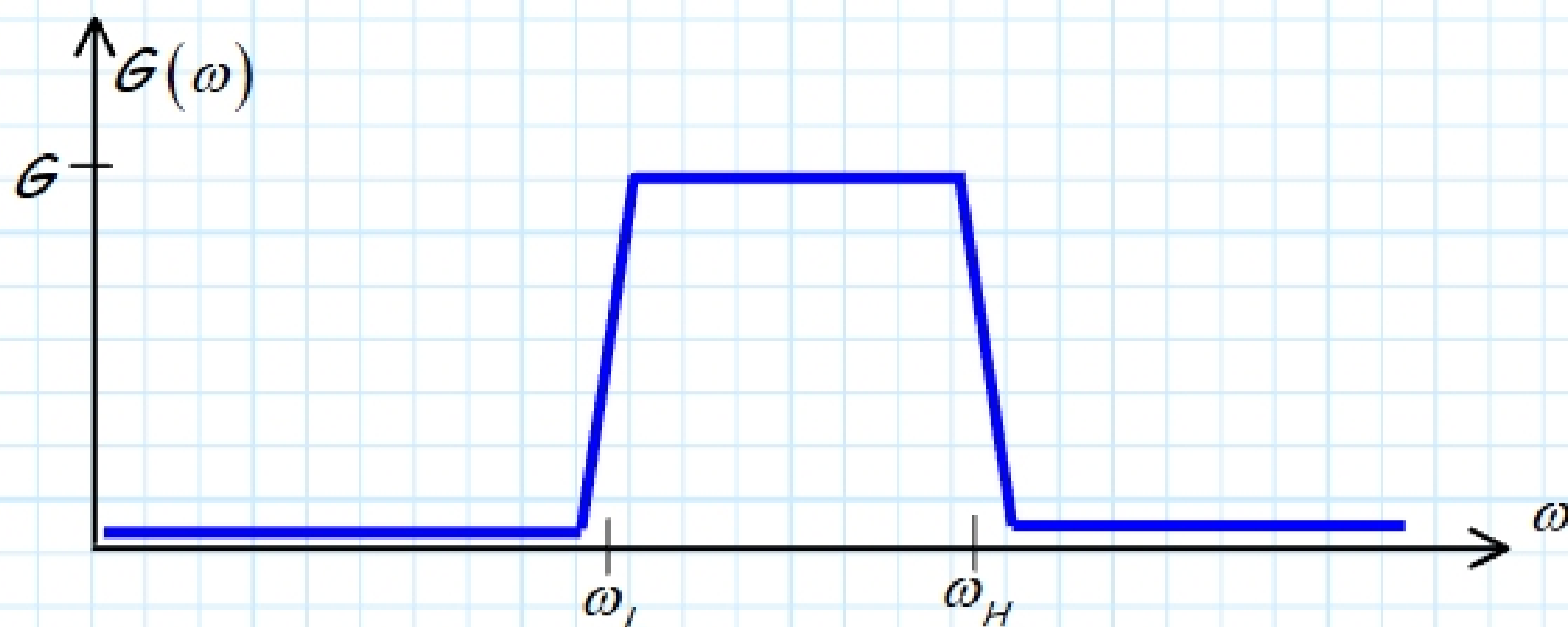
Clearly, an amplifier must be an **active** device!

As discussed earlier, the gain of an amplifier will change with signal frequency:

$$G(\omega) = |S_{21}(\omega)|^2$$

When radio engineers speak of amplifier **gain**, they almost always are speaking of this **power gain G**. However, they do not generally state it as a specific function of frequency!

Rather, amplifier gain is typically specified as a **numeric** value such as $G = 20$ or $G = 13$ dB. This value is a statement of the approximate amplifier gain **within** the amplifier **bandwidth**.

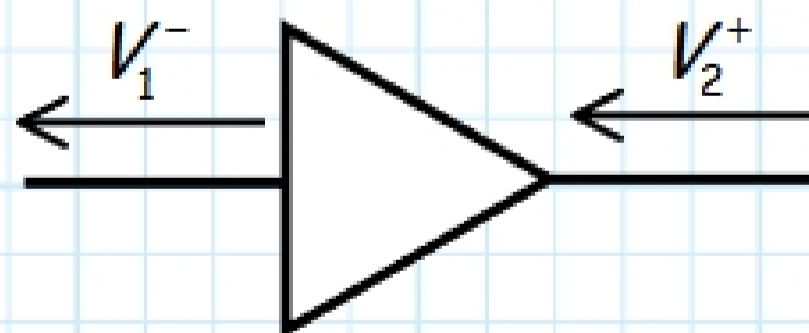


Thus, amplifier **gain** and **bandwidth** are the two most fundamental performance specifications of any microwave amplifier—together they (approximately) describe the amplifier transfer function!

Additionally, radio engineers almost always speak of amplifier gain in **decibels (dB)**:

$$G(\text{dB}) = 10 \log_{10} G$$

Finally, let's consider S_{12} . This scattering parameter relates the wave into port 2 (the output) to the wave out of port 1 (the input).



Q: *Are amplifiers reciprocal devices? In other words, is $S_{12} = S_{21}$??*