S Parameters

- **Scattering parameters** - also known as S-parameters — refer to the elements in a mathematical matrix describing the behavior of an electrical network (or circuit) when it is being stimulated by an electrical signal.
- At high frequencies, it becomes difficult to measure **voltages and currents** directly.
  Consequently, S-parameters describe the input-output relationships of **power waves** between the **ports** of an electrical network.

Benefits of Using S-parameters :

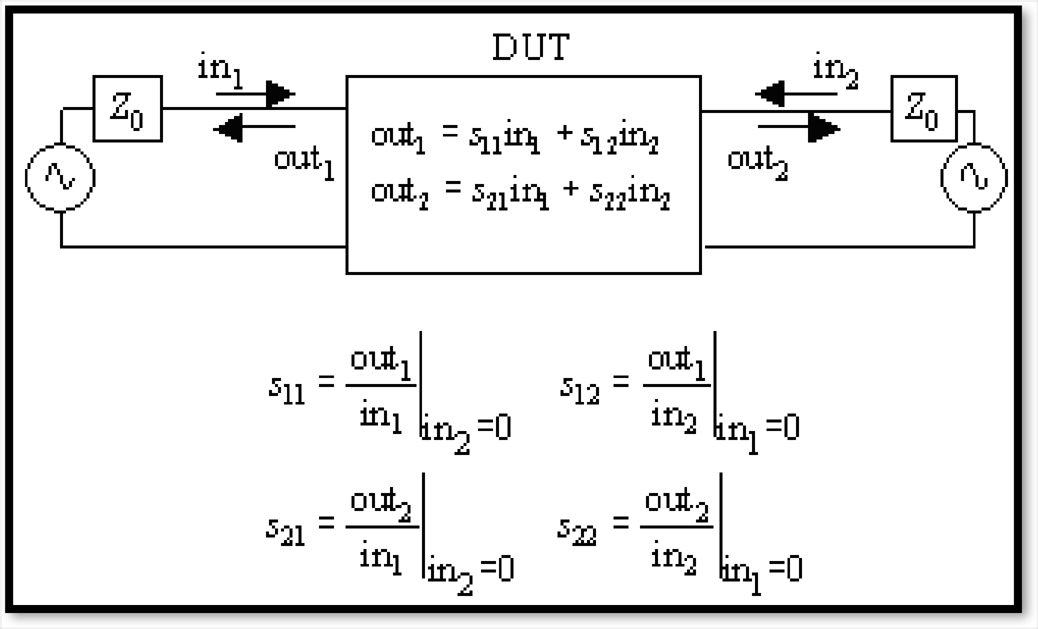
S-parameters provide engineers with valuable information concerning the performance of linear electrical networks, including
RF circuits, amplifiers, and filters.

This information includes:

•Details of signal magnitude, phase, reflection, and attenuation

•Locations of signal losses and impedance mismatches

•Transmission line parameters, such as R, L, C, G, TD, and Z0



For a matched two-port network, the reflection coefficients are zero and

$$S_{11} = S_{22} = 0 \tag{10.138}$$

The input reflection coefficient can be expressed in terms of the S-parameters and the load Z_L as

$$\Gamma_i = \frac{b_1}{a_1} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} \tag{10.139}$$

where

$$\Gamma_L = \frac{Z_L - Z_o}{Z_L + Z_o} \tag{10.140}$$

Similarly, the output reflection coefficient (with $V_g = 0$) can be expressed in terms of the generator impedance Z_g and the S-parameters as

$$\Gamma_o = \left.\frac{b_2}{a_2}\right|_{V_g=0} = S_{22} + \frac{S_{12}S_{21}\Gamma_g}{1 - S_{11}\Gamma_g} \tag{10.141}$$

where

$$\Gamma_g = \frac{Z_g - Z_o}{Z_g + Z_o} \tag{10.142}$$

Thus, the S-matrix for a two-port network is written as:

$$\begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix}$$

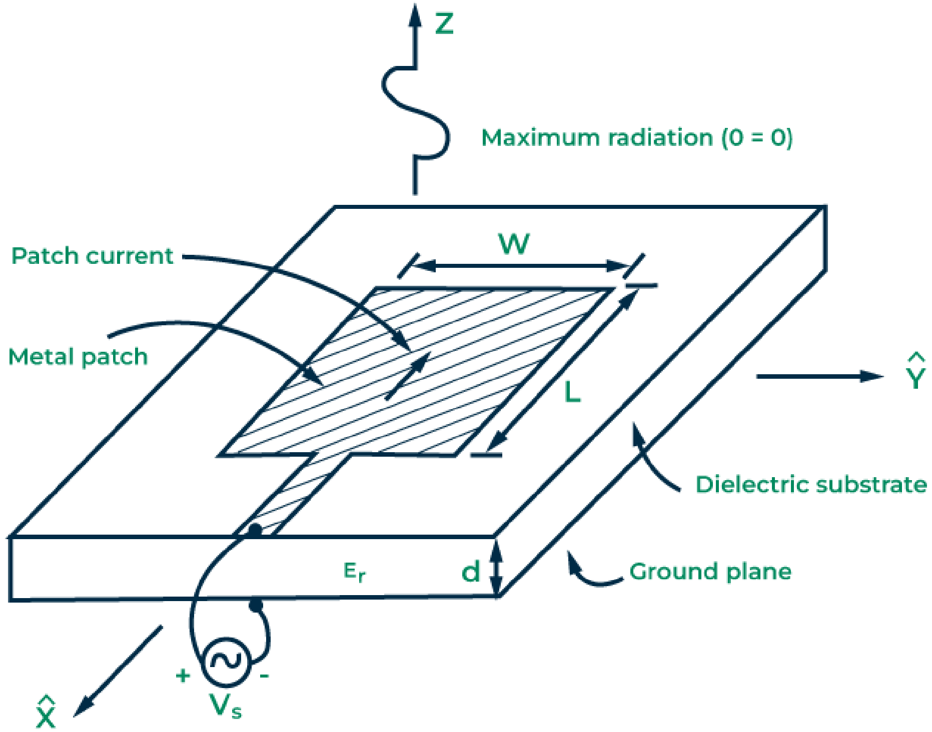
Where:

- S_{11} is input port reflection coefficient
- S_{22} is the output port reflection coefficient
- S_{12} is the input port transmission coefficient (or “reverse voltage gain”)
- S_{21} is the transmission coefficient (or “forward voltage gain”)

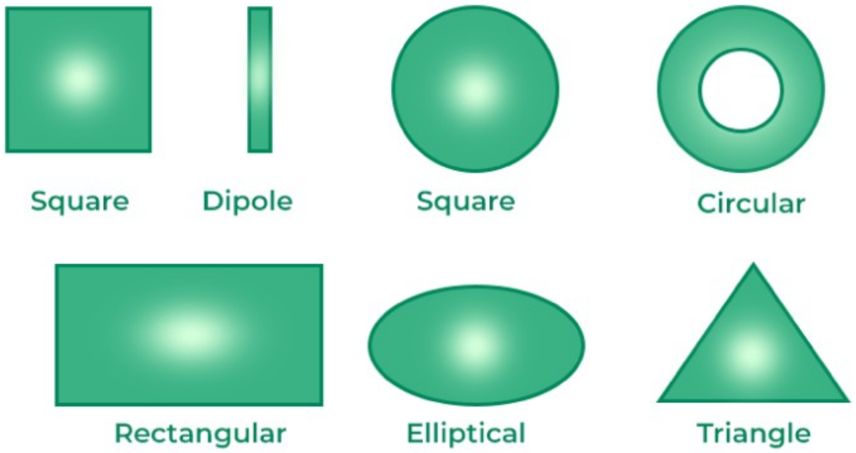
S_{11} **(Reflection Coefficient)** → Measures **how much signal is reflected** (impedance matching).

S_{21} **(Transmission Coefficient)** → Measures **how much signal passes through** the system.

Microstrip Patch Antenna



Types of Microstrip Patch Antenna



Microstrip Patch Antenna Calculation

Step 1: Calculation of the Width (W) -

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

Step 2: Calculation of the Effective Dielectric Constant. This is based on the height, dielectric constant of the dielectric and the calculated width of the patch antenna.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Step 3: Calculation of the Effective length

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}}$$

Step 4: Calculation of the length extension ΔL

$$\Delta L = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Step 5: Calculation of actual length of the patch

$$L = L_{eff} - 2\Delta L$$

Where the following parameters are used

f_0 is the Resonance Frequency

W is the Width of the Patch

L is the Length of the Patch

h is the thickness

ε_r is the relative Permittivity of the dielectric substrate

c is the Speed of light: 3×10^8

https://www.everythingrf.com/rf-calculators/microstrip-patch-antenna-calculator