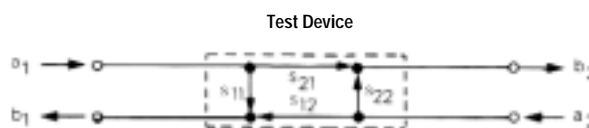


S-Parameters/Return Loss/Smith Chart

S-parameters (scattering parameters) are a convention for characterizing RF & microwave devices, consisting of reflection and transmission coefficients—familiar concepts to designers. Transmission coefficients are commonly referred to as gains or attenuations, reflection coefficients relate to return losses and VSWRs (voltage standing wave ratios).

Conceptually, “s” parameters are like “h”, “y”, or “z” parameters because they describe the inputs and outputs of a black box. The inputs and outputs are in terms of power for “s” parameters; for “h”, “y”, and “z” parameters, they are voltages and currents. Using the convention that “a” is a signal into a part and “b” is a signal out, the figure below helps to explain “s” parameters.



In this figure, “a” and “b” are the square roots of power; $(a_1)^2$ is the power incident at port 1 and $(b_2)^2$ is the power leaving port 2. The diagram shows the relationship between the “s” parameters and the “a”’s and “b”’s. For example, a signal, a_1 , is partially reflected at port 1; the rest of the signal is transmitted through the device and out of port 2. The fraction of a_1 that is reflected at port 1 is s_{11} ; the fraction of a_1 that is transmitted is s_{21} . Similarly, the fraction of a_2 that is reflected at port 2 is s_{22} , and the fraction s_{12} is transmitted. The signal, b_1 , leaving port 1 is the sum of the fraction of a_1 that is reflected at port 1 and the fraction of a_2 that is transmitted from port 2. Thus, the outputs can be related to the inputs by the equations:

$$b_1 = s_{11}a_1 + s_{12}a_2$$

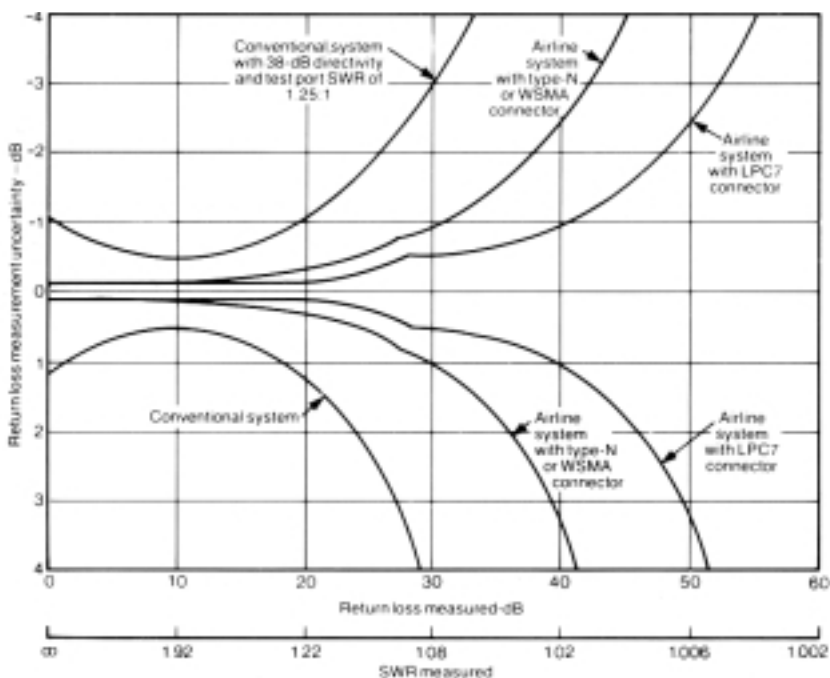
$$b_2 = s_{21}a_1 + s_{22}a_2$$

when $a_2 = 0$

and when $a_1 = 0$

$$s_{11} = \frac{b_1}{a_1} \quad s_{21} = \frac{b_2}{a_1}$$

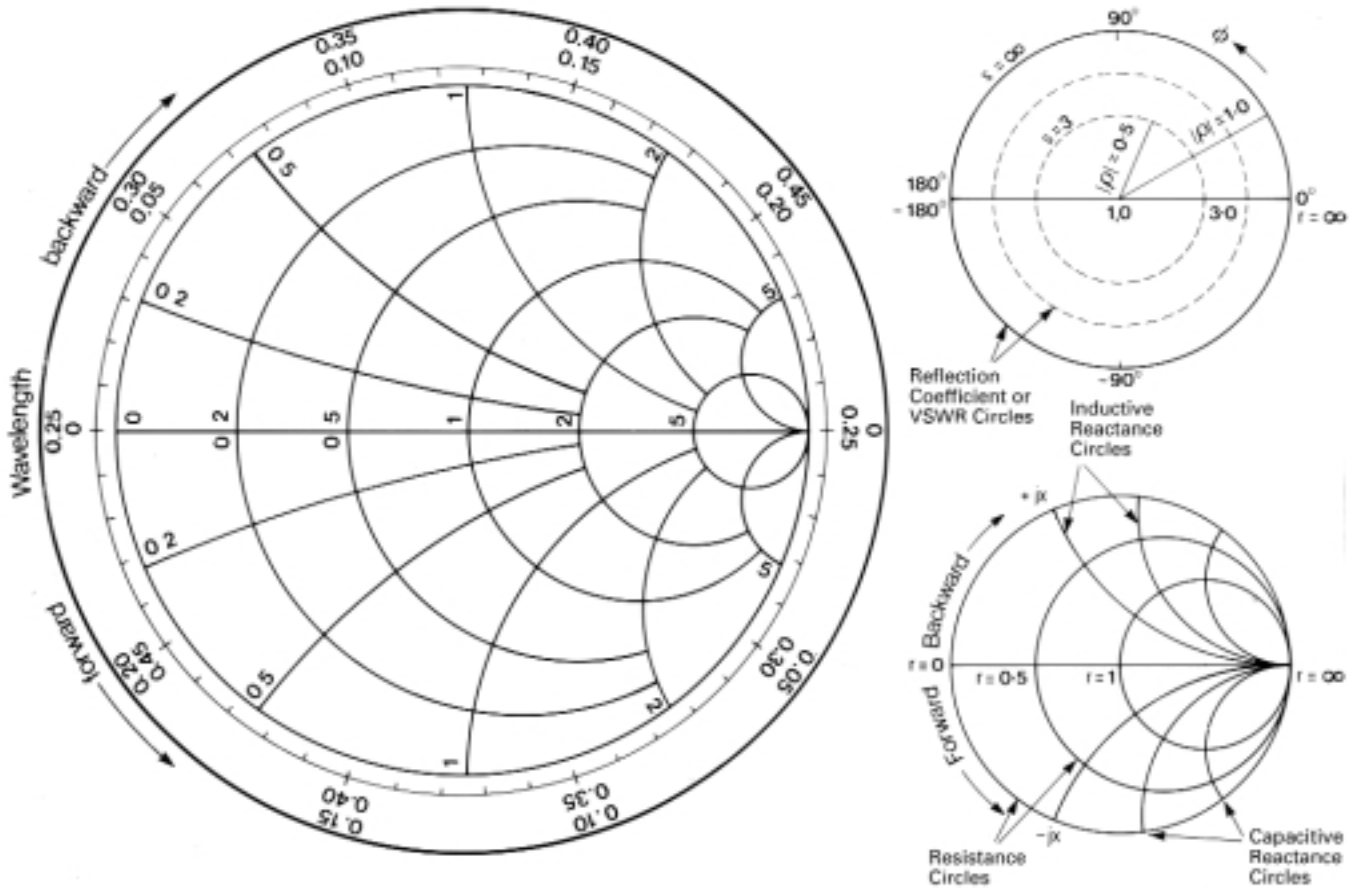
$$s_{12} = \frac{b_1}{a_2} \quad s_{22} = \frac{b_2}{a_2}$$



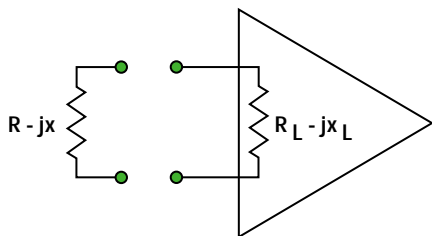
Continued page 2



S-Parameters/Return Loss/Smith Chart, continued



Noise Power at Standard Temperature



$k = 1.38 \times 10^{-23}$ joule /k
 $T =$ Temperature (K)
 $B =$ Bandwidth (Hz)

Available Noise Power*

$$P_{av} = kTB$$

At 290K $P_{av} = 4 \times 10^{-21}$ W/Hz = -174dBm/Hz

In deep space $kT =$ -198dBm/Hz

* Noise figure is defined when input is terminated at 290 Kelvins.

Noise Figure (NF_{dB})

$$NF_{dB} = 10 \log_{10} \frac{S_i/N_i}{S_o/N_o}$$

Where NF_{dB} = noise figure (dB)

S_i/N_i = input signal-to-noise ratio

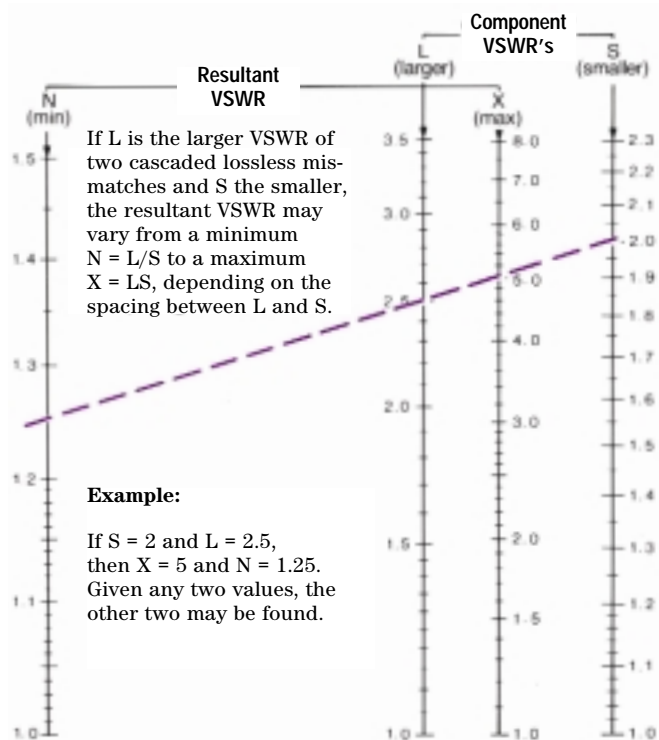
S_o/N_o = output signal-to-noise ratio



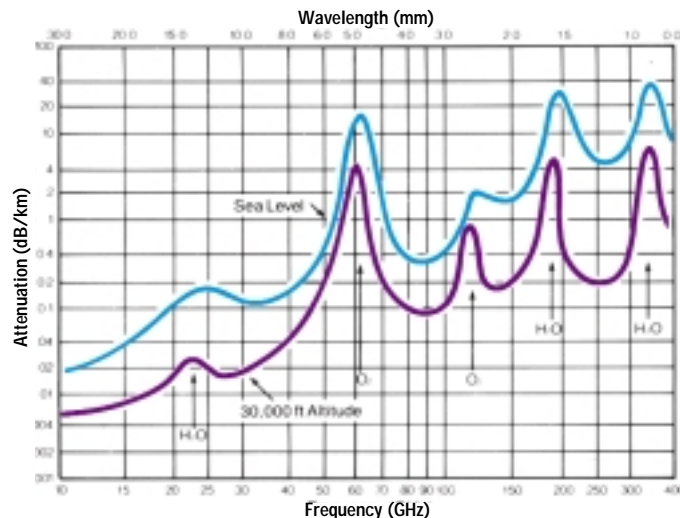
Agilent Technologies

Innovating the HP Way

Maximum and Minimum Resultant VSWR from Two Mismatches

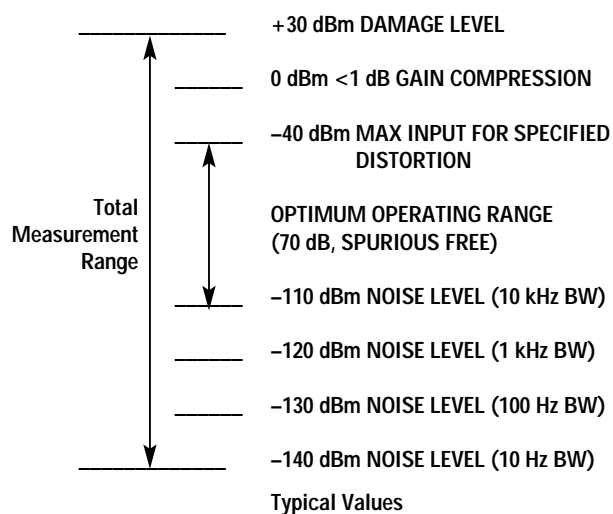


Millimeter-Wave Transmission Attenuation Curves

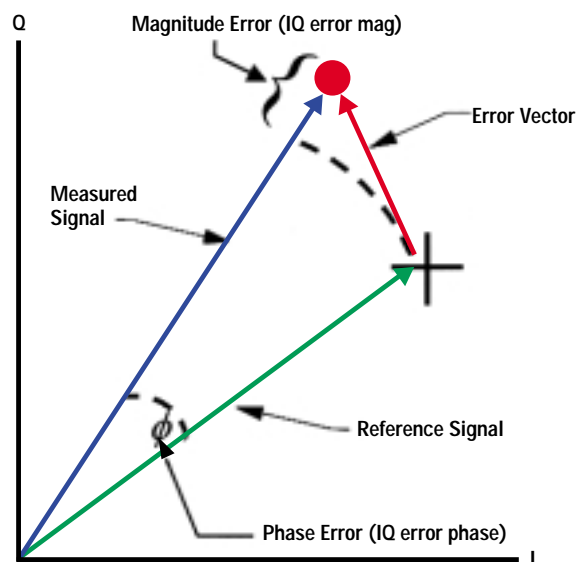


The atmospheric attenuation of mm-wave signals varies greatly, allowing for long-range exploitation by operating in the windows at 35, 94, 140, and 220 GHz, or for short-range, intercept resistant communications at 44 to 65 GHz.

Spectrum Analyzer Display Range



Modulation Quality: Error Vector Magnitude



Microwave Formulae

Wavelength (λ)

$$\lambda(\text{centimeters}) = \frac{3 \times 10^{10}}{f}$$

$$\lambda(\text{meters}) = \frac{3 \times 10^{10}}{f}$$

where f = frequency (hertz)

dB (Power and Voltage)

$$\text{dB}_{(\text{power})} = 10 \log_{10} \frac{P1}{P2}$$

$$\text{dB}_{(\text{power})} = 20 \log_{10} \frac{E1}{E2}$$

where $P1$ & $P2$ = system powers
 $E1$ & $E2$ = system voltages

Characteristic Impedance (Z_0) of RF Cable

$$Z_0 = \frac{138}{\sqrt{\epsilon_r}} \log_{10} \frac{D}{d}$$

where ϵ_r = relative dielectric constant

D = inside diameter of outer conductor

d = outside diameter of inner conductor

Velocity Factor

$$v = \frac{1}{\sqrt{\epsilon_r}} \times 100$$

where ϵ_r = relative dielectric constant

Noise Figure (NF_{dB})

$$NF_{dB} = 10 \log_{10} \frac{S_i/N_i}{S_o/N_o}$$

Where NF_{dB} = noise figure (dB)

S_i/N_i = input signal-to-noise ratio

S_o/N_o = output signal-to-noise ratio

Reflection Coefficient ρ

$$\rho = \frac{VSWR - 1}{VSWR + 1}$$

where VSWR = Voltage Standing Wave Ratio

Return Loss in dB

$$\text{dB} = 20 \log_{10} |\rho|$$

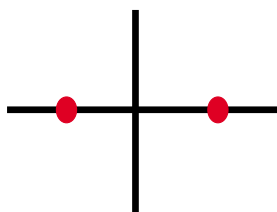
where ρ = reflection coefficient

VSWR

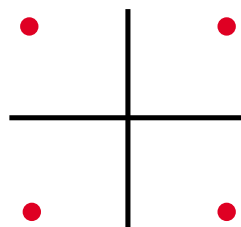
$$VSWR = \frac{1 + \rho}{1 - \rho}$$

where ρ = reflection coefficient

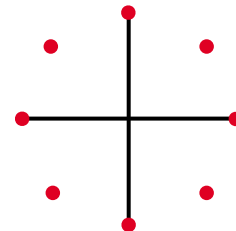
Digital Modulation Type and Constellation



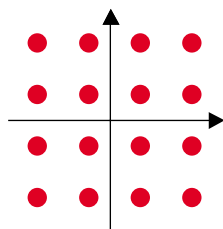
BPSK
 One Bit Per Symbol
 Symbol Rate = Bit Rate



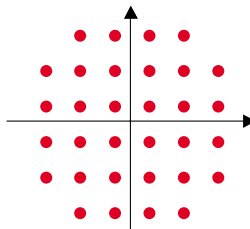
QPSK
 Two Bits Per Symbol
 Symbol Rate = 1/2 Bit Rate



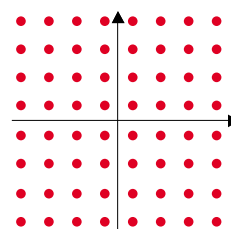
Pi/4DQPSK: Two Bits Per Symbol
 Symbol Rate = 1/2 Bit Rate
 or **8PSK: Three Bits Per Symbol**
 Symbol Rate = 1/3 Bit Rate



16 QAM
 Four Bits Per Symbol
 Symbol Rate = 1/4 Bit Rate



32 QAM
 Five Bits Per Symbol
 Symbol Rate = 1/5 Bit Rate



64 QAM
 Six Bits Per Symbol
 Symbol Rate = 1/6 Bit Rate

