# 50 Ω, VSWR and return loss

A 50 Ω load at the end of a 50 Ω line absorbs everything; anything else reflects part of the wave. The reflection coefficient, return loss and VSWR are three ways of saying how much.

## One reflection, three names

| | | |
|---|---|---|
| **Reflection coefficient** | $\Gamma = (Z - Z_0)/(Z + Z_0)$ | 50 Ω load: 0. Open: +1. Short: −1, everything comes back. |
| **Return loss** | $\mathrm{RL} = -20 \log_{10} \lvert\Gamma\rvert$ | In dB, bigger is better. |
| **VSWR** | $\mathrm{VSWR} = (1 + \lvert\Gamma\rvert)/(1 - \lvert\Gamma\rvert)$ | Peak divided by dip of the voltage on the line. |
| **Back from VSWR** | $\lvert\Gamma\rvert = (\mathrm{VSWR} - 1)/(\mathrm{VSWR} + 1)$ | VSWR 1.25: $\lvert\Gamma\rvert$ = 0.111, return loss 19.1 dB. |
| **Power reflected** | $\lvert\Gamma\rvert^2$ | VSWR 2: about 11%. |
| **Mismatch loss** | $-10 \log_{10} (1 - \lvert\Gamma\rvert^2)$ dB | VSWR 2 sounds bad but loses only 0.51 dB. |

## Lines, cables and why 50 Ω

| | | |
|---|---|---|
| **75 Ω on a 50 Ω line** | $\Gamma = (75 - 50)/(75 + 50) = 0.2$ | Return loss 14 dB, VSWR 1.5. |
| **Standing-wave ripple** | repeats every $\lambda/2$ of line | At distance z from the load, the reflection has covered 2z more than the incoming wave. |
| **Through a test cable** | $\mathrm{RL}_{\mathrm{meas}} = \mathrm{RL} + 2L_{\mathrm{cable}}$ | A 1 dB cable makes a load look 2 dB better. Calibrate at the cable end. |
| **Air-filled coax** | $Z_0 = 60 \ln(D/d)$ | Lowest conductor loss at D/d ≈ 3.59 (about 77 Ω), most power at D/d = √e (30 Ω). 50 Ω sits between. |

## One number, three names (computed from the formulas)

| VSWR | $\lvert\Gamma\rvert$ | Return loss | Power reflected | Mismatch loss |
|---|---|---|---|---|
| 1.1 | 0.048 | 26.4 dB | 0.2% | 0.01 dB |
| 1.25 | 0.111 | 19.1 dB | 1.2% | 0.05 dB |
| 1.5 | 0.200 | 14.0 dB | 4.0% | 0.18 dB |
| 2.0 | 0.333 | 9.5 dB | 11.1% | 0.51 dB |
| 3.0 | 0.500 | 6.0 dB | 25.0% | 1.25 dB |

## Watch out

- The SMA male 50 Ω load we stock: VSWR ≤1.25 from DC to 18 GHz (return loss ≥19.1 dB), 0.5 W. For bench signals, not a transmitter on full power: use a high-power dummy load or a pad rated for the full power in front.
- In a VNA calibration the result can be no better than the load used: this load cannot show a reflection smaller than its own, about 19 dB return loss.
- A VNA result includes everything after the calibration plane. Cable loss counts twice in return loss, so test cables make an antenna look better than it is.
- Even a small mismatch loss matters elsewhere: a transmitter may not like the reflected power, mismatch at both ends makes levels depend on cable length, and every reflection is a measurement error term.

Full article, derivations and figures: kymopsis.com/50-ohm-vswr-return-loss-explained/

Formulas and values from the chapter; conditions as stated there. Free to print and share.