Quarter-Wave Transformer: Impedance, Length and Bandwidth

Line impedance and physical length of a quarter-wave matching section between two resistances, and its fractional bandwidth for a maximum VSWR.

Method: Quarter-wave transformer and its bandwidth

Input parameters

Unit system: SI

Parameter	Value	Unit
Feed line impedance	50.000	Ω
Load resistance	100.00	Ω
Design frequency	2.4000	GHz
Velocity factor of the line	66.000	%
Highest acceptable VSWR	1.5000	

Calculated results

Parameter	Value	Unit
Impedance of the quarter-wave section	70.711	Ω
Physical length	20.611	mm
Reflection coefficient at the VSWR limit	0.20000	
Fractional bandwidth for that VSWR	78.365	%

Notes for this case

• A line a quarter wavelength long transforms a load Z_L into Z_T²/Z_L, so Z_T = √(Z₀Z_L) matches it. The physical length is a quarter of the free-space wavelength times the line's velocity factor. The match is exact only at the design frequency; the band over which the VSWR stays below S_max is Δf/f₀ = 2 − (4/π) arccos[Γ_m/√(1 − Γ_m²) · 2√(Z₀Z_L)/|Z_L − Z₀|] (TEM line). Larger impedance ratios give narrower bands; cascade several sections for wider ones.

Formula and method

$$Z_T = \sqrt{Z_0 Z_L}, \quad \ell = \frac{v_f c}{4 f_0}, \quad \frac{\Delta f}{f_0} = 2 - \frac{4}{\pi} \arccos\left[\frac{\Gamma_m}{\sqrt{1-\Gamma_m^2}} \frac{2\sqrt{Z_0 Z_L}}{|Z_L - Z_0|}\right]$$

Variables

Z_0	Feed line impedance	Ω
Z_L	Load resistance	Ω
f_0	Design frequency	1/s
v_f	Velocity factor of the line	-
S_{max}	Highest acceptable VSWR	-
Z_T	Impedance of the quarter-wave section	Ω
ℓ	Physical length	m
Γ_m	Reflection coefficient at the VSWR limit	-
$\Delta f / f_0$	Fractional bandwidth for that VSWR	-

Method and standards

Quarter-wave transformer.

Assumptions and limits

- Lossless TEM line; resistive load.

References

Quarter-wave transformer and its bandwidth

Report details

Report reference	FCC-96A7-0QNQ (the same inputs always give the same reference)
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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/electrical/electronics/quarter-wave-transformer

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.