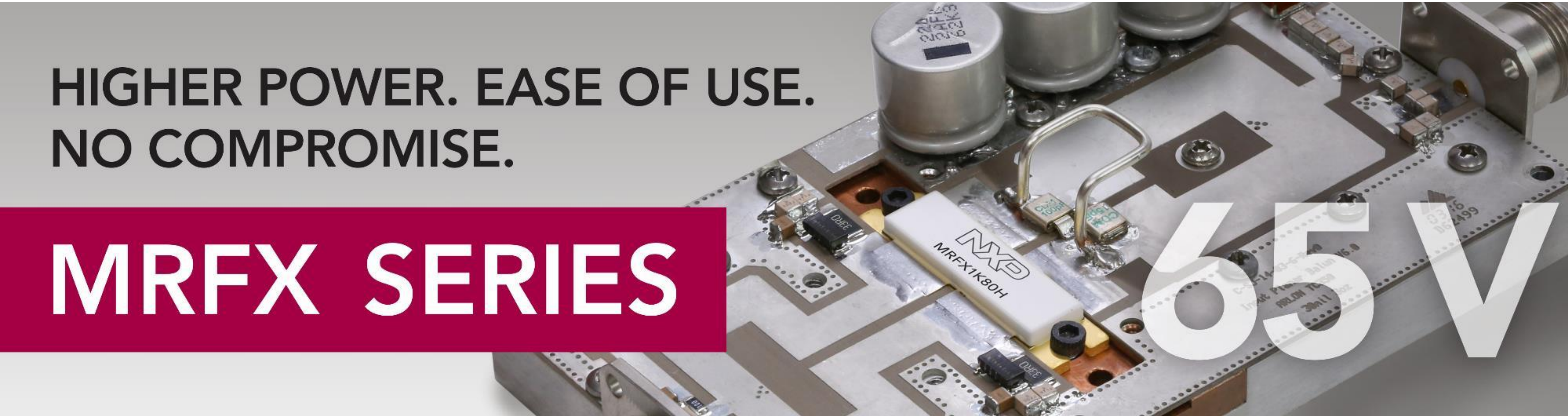
65 V LDMOS OVERVIEW



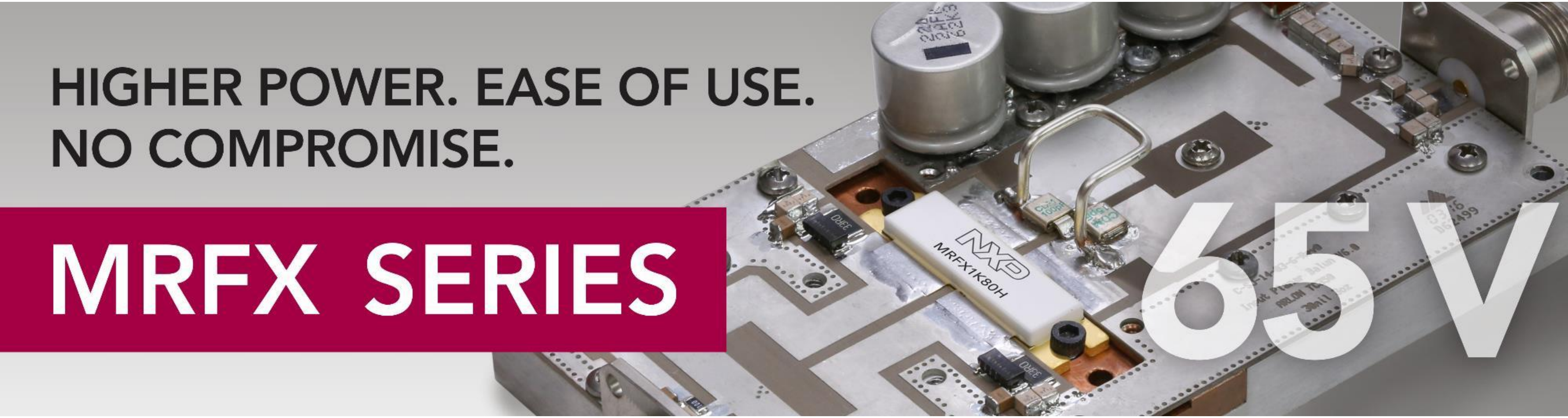
SECURE CONNECTIONS
FOR A SMARTER WORLD

Richardson RFPD, Inc

Global RF, Wireless, Industrial IoT, Energy & Power Expert

- Electronic Components & Engineered Solutions
  - Deep and Broad Selection of Quality Components, Modules and Kits
- Expert Team of RF Designers and Engineers
  - ~245 Customer-Facing Team Members
- Value-Added Services
  - Design-In Support, Component Binning/Selecting, and Application Engineering
- Integrated Supply Chain and Global Logistic Centers
  - Reno, Nevada; Hong Kong, China; Venlo, Netherlands
- 35 Sales Offices and Locations, 6 Engineering Centers
- Richardson RFPD, Inc. - Wholly Owned Subsidiary of Arrow Electronics

65 V LDMOS OVERVIEW



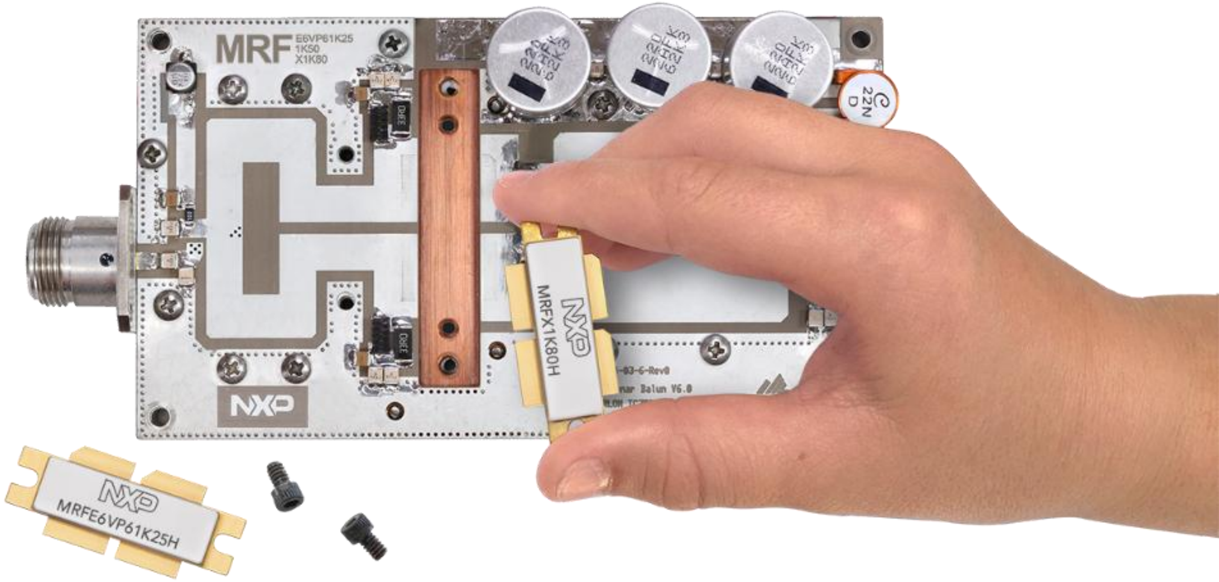
SECURE CONNECTIONS
FOR A SMARTER WORLD

Introduction

- NXP is announcing a new LDMOS technology using 65 V drain voltage, focused on **ease of use**.
  – Higher voltage enables a higher RF output power with no compromise.

- The first transistor of the 65 V MRF**X** series is the MRF**X**1K80, the industry's most powerful CW RF transistor: 1800 W.

- The MRF**X**1K80 is pin-compatible with existing 50 V transistors, to reduce design cycle times.



A Brief History of LDMOS for ISM and broadcast applications

- **1990s:** first **LDMOS** transistor created by the Motorola RF power team.
- **2006**: introduction of the first **1kW** LDMOS transistor by Freescale, followed by four other lower power devices.
- **2010-2012**: Freescale launched industry-first portfolio of 5 **extremely rugged** 50 V LDMOS transistors in ceramic packaging, from 25 to 1250 W.
- **2014-2015**: complemented this portfolio with 5 transistors in **plastic package**, enabling lower thermal resistance.
- **2016**: NXP (ex Freescale) launched the 1500 W **MRF1K50H**, pushing 50 V LDMOS close to its limits of usability (higher power levels at 50 V are challenging to match to 50 ohm).
- **2017**: introducing the MRF**X** series with the 1800 W **MRFX1K80H**, based on new 65 V LDMOS technology developed in NXP's internal fab. Designed for ease of use.

Introducing NXP's new 65 V LDMOS

LDMOS Technology	Very High Voltage	Very High Voltage Extremely rugged	Extra High Voltage Extremely Rugged
Drain voltage	Up to 50 V	Up to 50 V	Up to 65 V
Max output power in NI-1230 package	1000 W CW	1500 W+ CW	1800 W+ CW
Breakdown voltage (min)	110 V	133 V	182 V
VSWR	10:1	65:1	65:1
Product releases	*2006-2010*	*2010-*	*2017-*

Leveraging NXP's internal LDMOS manufacturing.

The 5 benefits of raising the drain voltage for LDMOS FETs

More power – Higher voltage enables higher power density, which helps reduce the number of transistors to combine.

Faster development time – With higher voltage, the output power can be increased while retaining a reasonable output impedance.

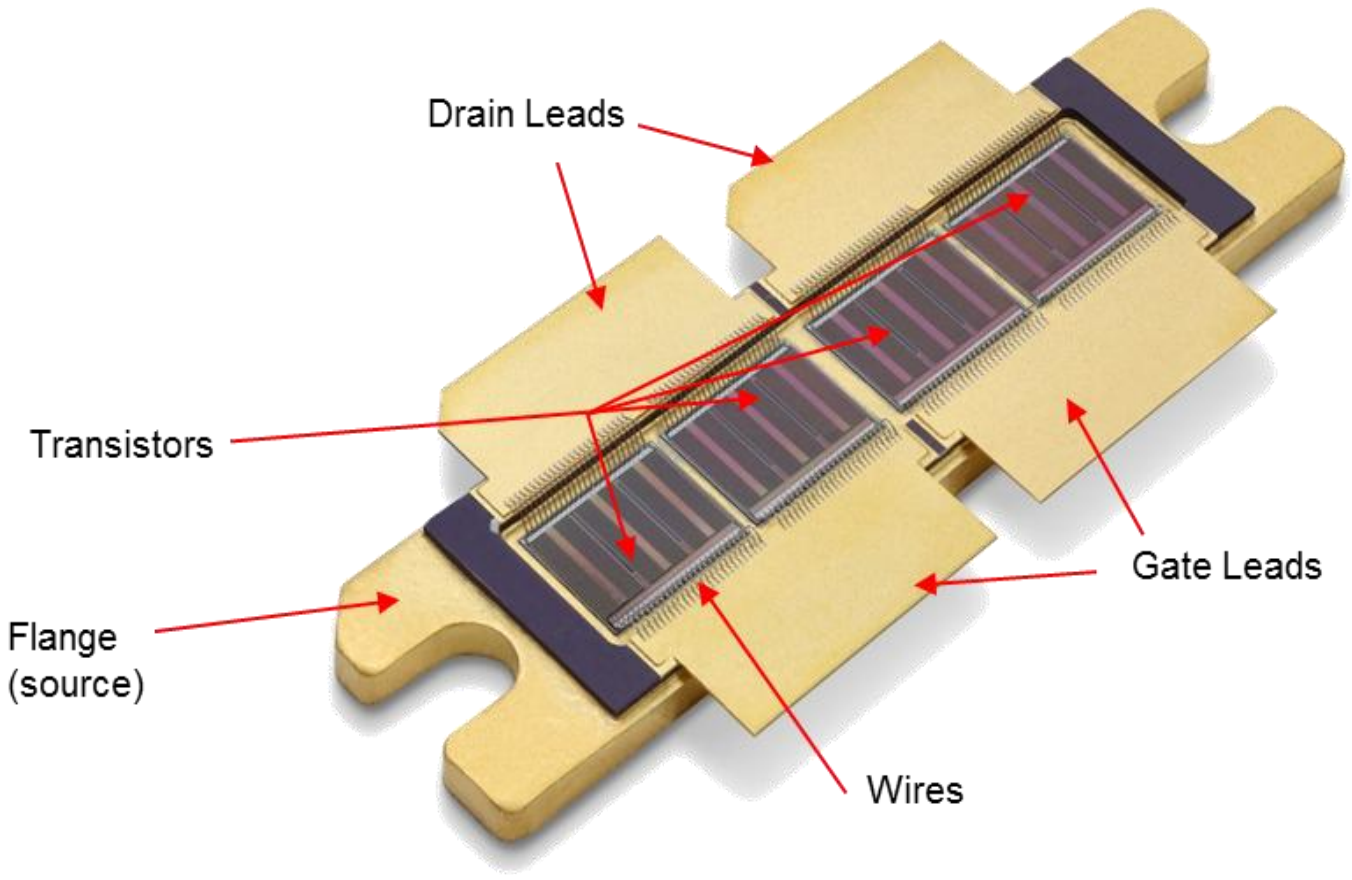
Design reuse – This impedance benefit also ensures pin-compatibility with current 50 V LDMOS transistors for better scalability.

Manageable current level – Higher voltage reduces the current losses in the system.

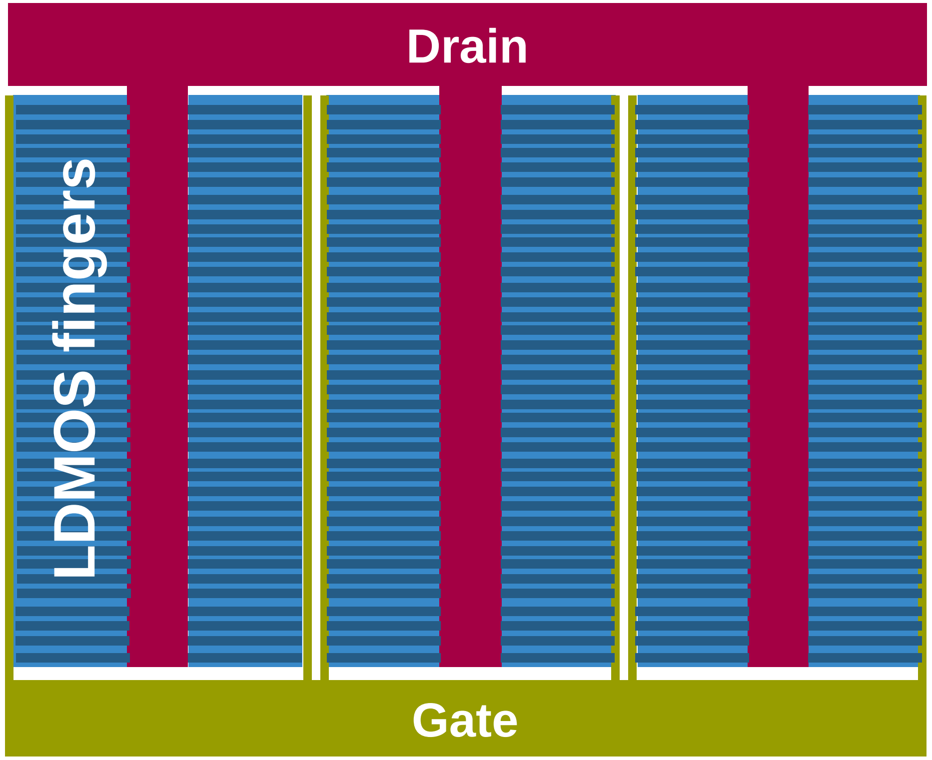
Wide safety margin – The higher breakdown voltage of 182 V improves ruggedness and allows for higher efficiency classes of operation.

LDMOS device overview

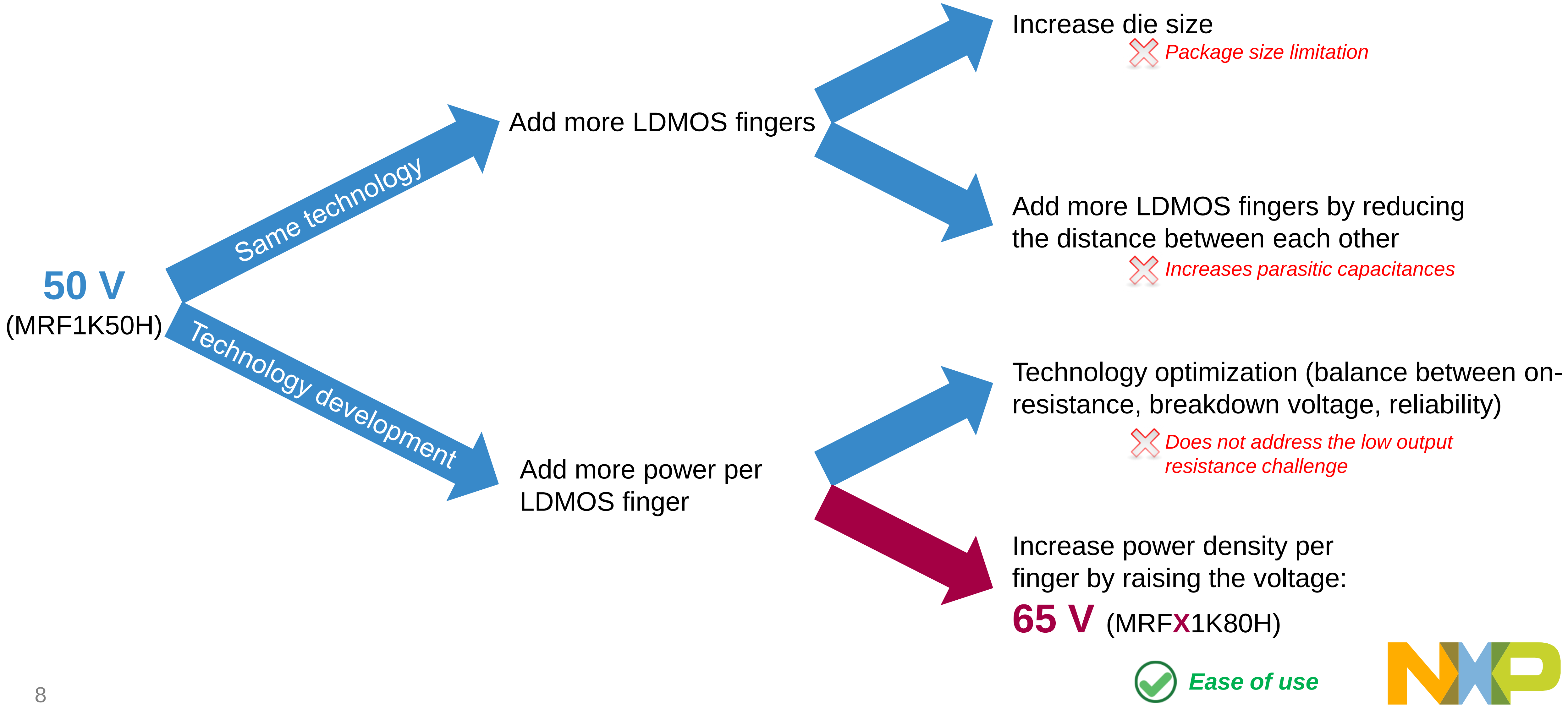
In NI-1230 air cavity ceramic package



Simplified view of an LDMOS die layout:

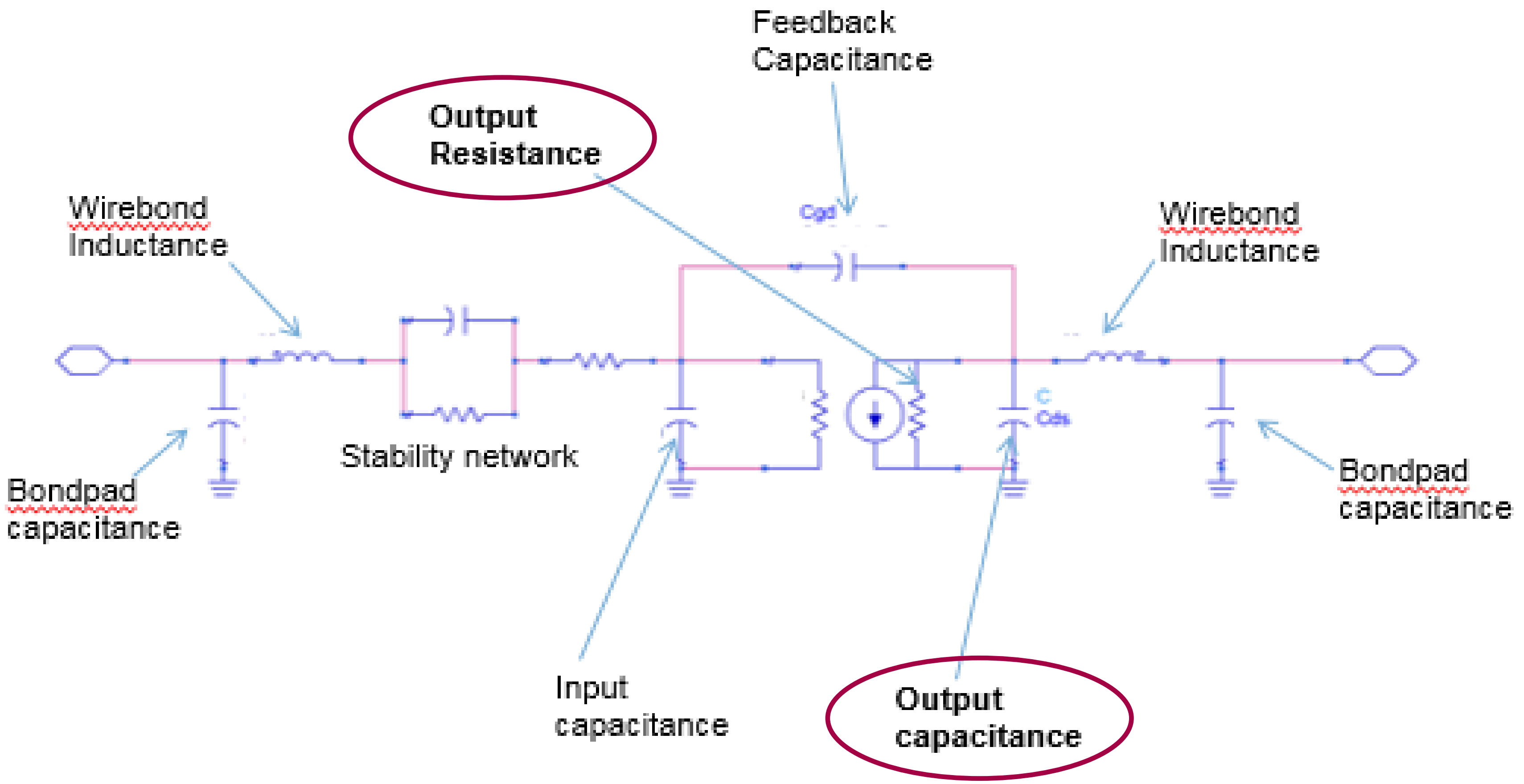


LDMOS technology design choices for higher power



High power LDMOS design challenge:

managing output resistance and capacitance for ease of use



Linear model of a high power LDMOS FET

NXP RF Technology Design Strategy

To keep a reasonable output impedance above 1500 W, NXP is raising the voltage

(formula for each side of a transistor, in HF frequencies)

Output impedance
Higher impedance makes it easier to match to 50 ohm.

$$R_L = \frac{V^2}{2P}$$

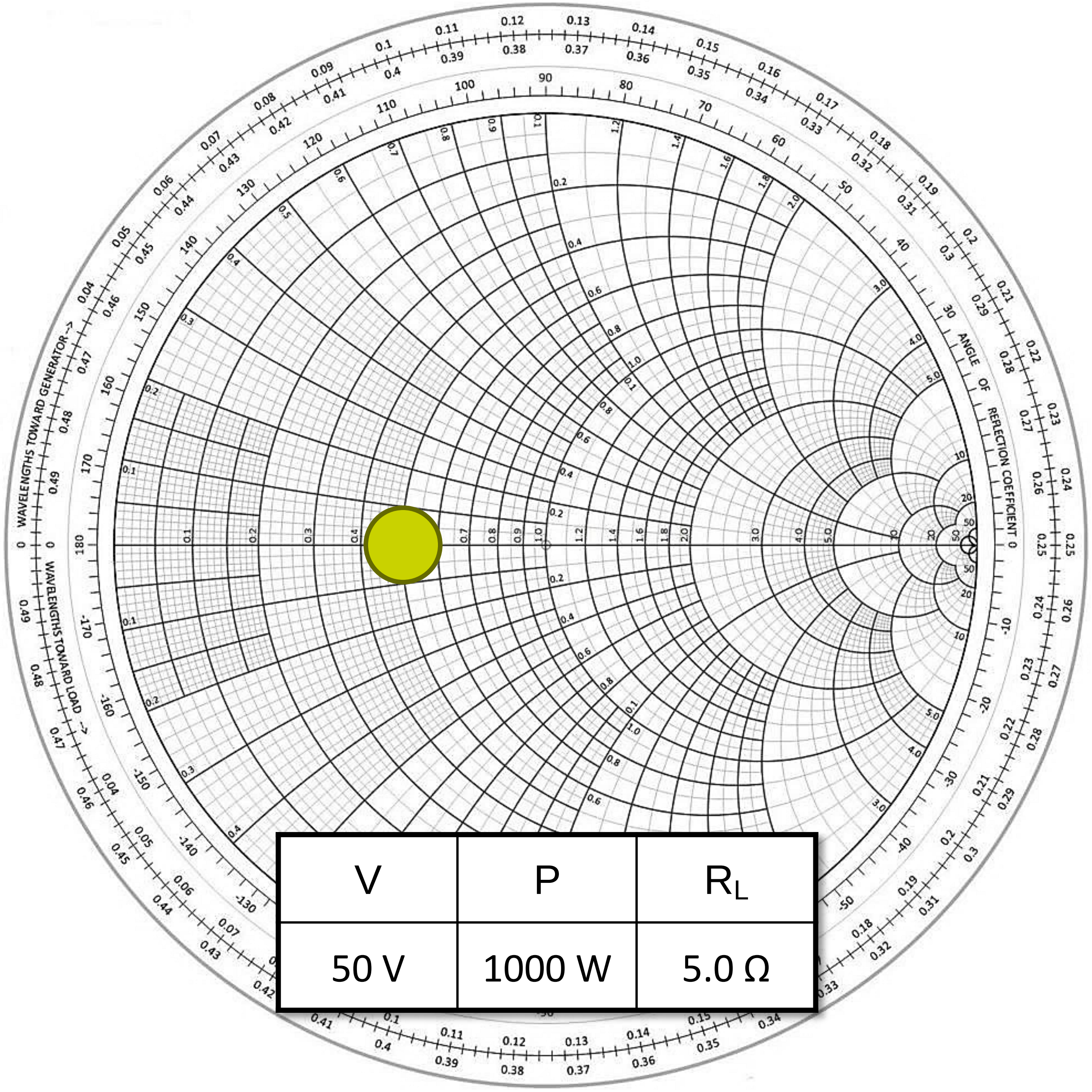
Drain voltage
NXP is raising the voltage V to increase the output power P, while keeping the output impedance R_L reasonable.
$R_L = (65^2 / 2x900W) \times 2$ sides = 4.7 ohm*
(transformation ratio to 50 ohms = ~10)

Output power.
NXP's competitors increase output power P while retaining V = 50 V. Consequence: reduced output resistance, making the transistors difficult to match and very challenging to use wideband.
$R_L = (50^2 / 2x900W) \times 2$ sides = 2.8 ohm*
(transformation ratio to 50 ohms = ~18)

*: examples for a 1800W push-pull transistor.

Higher output impedance

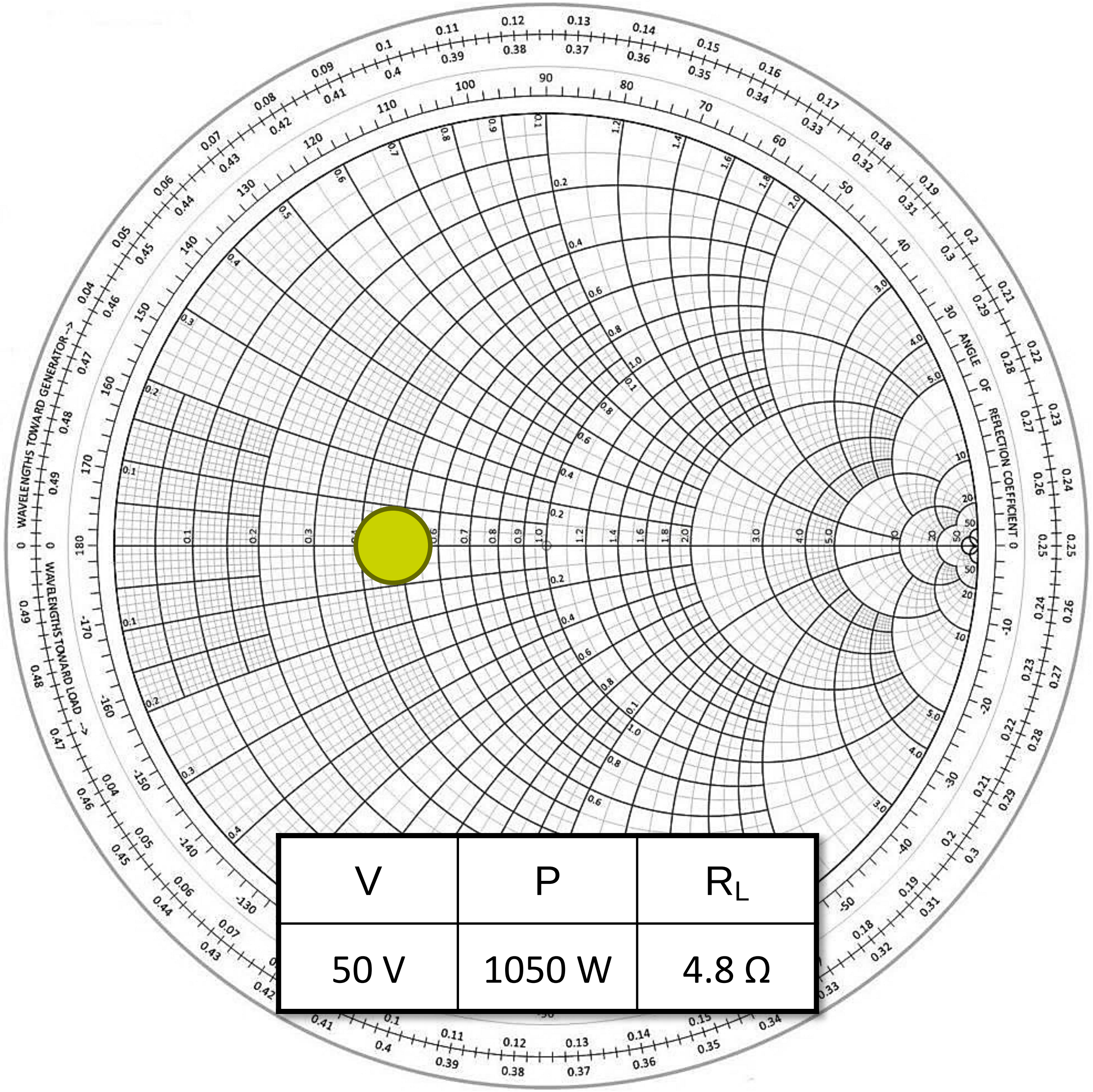
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1000 W	5.0 Ω

Higher output impedance

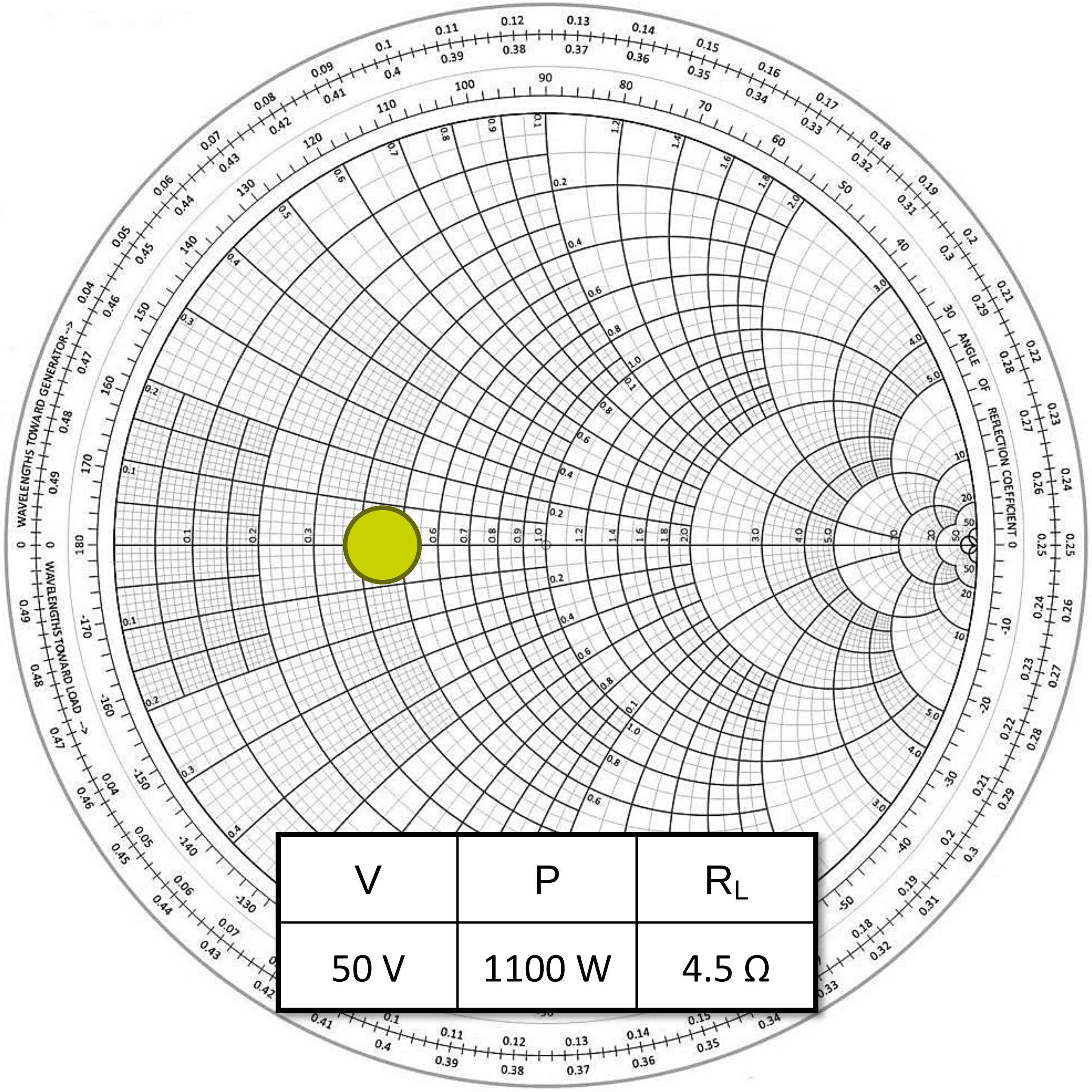
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1050 W	4.8 Ω

Higher output impedance

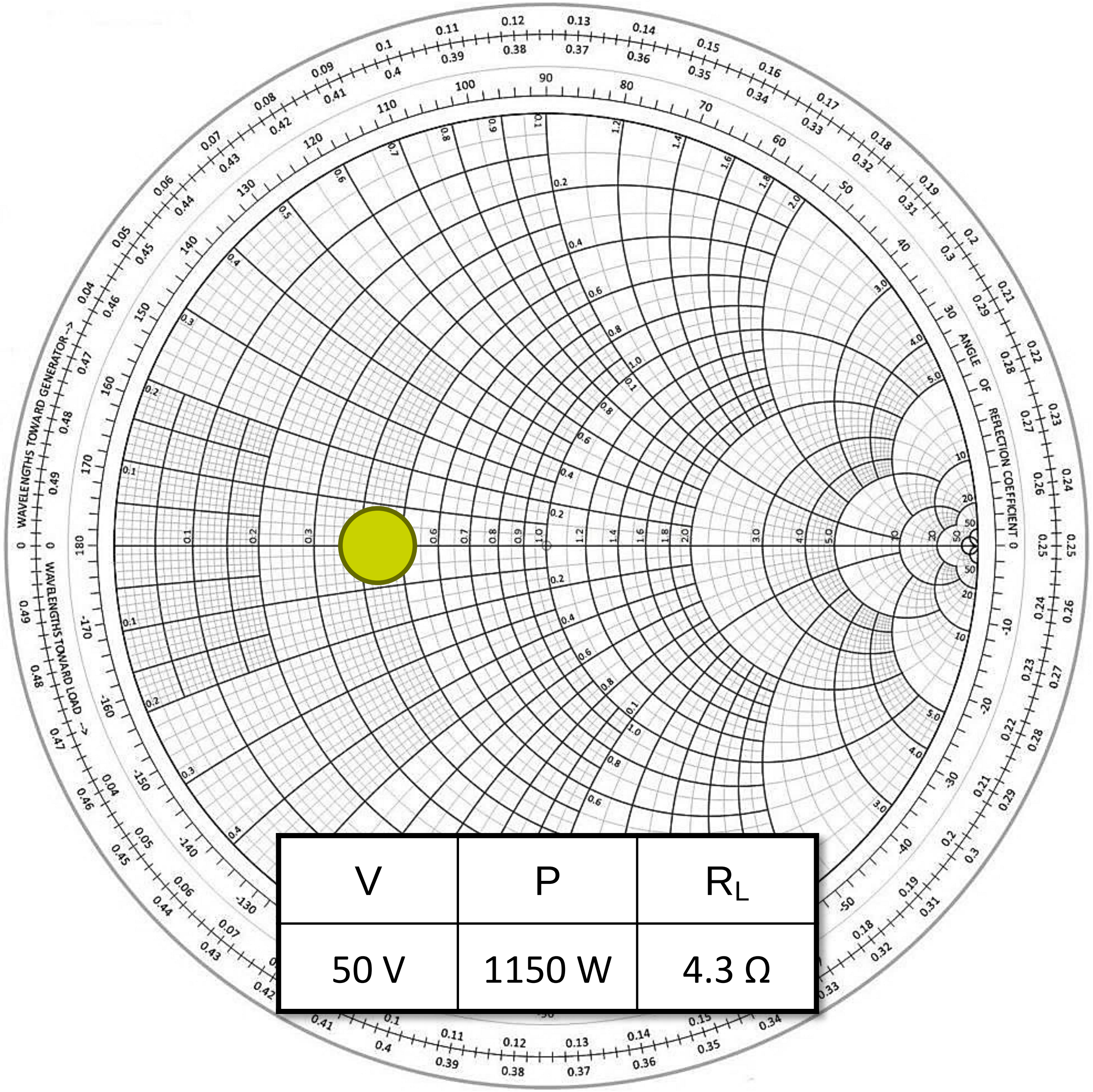
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1100 W	4.5 Ω

Higher output impedance

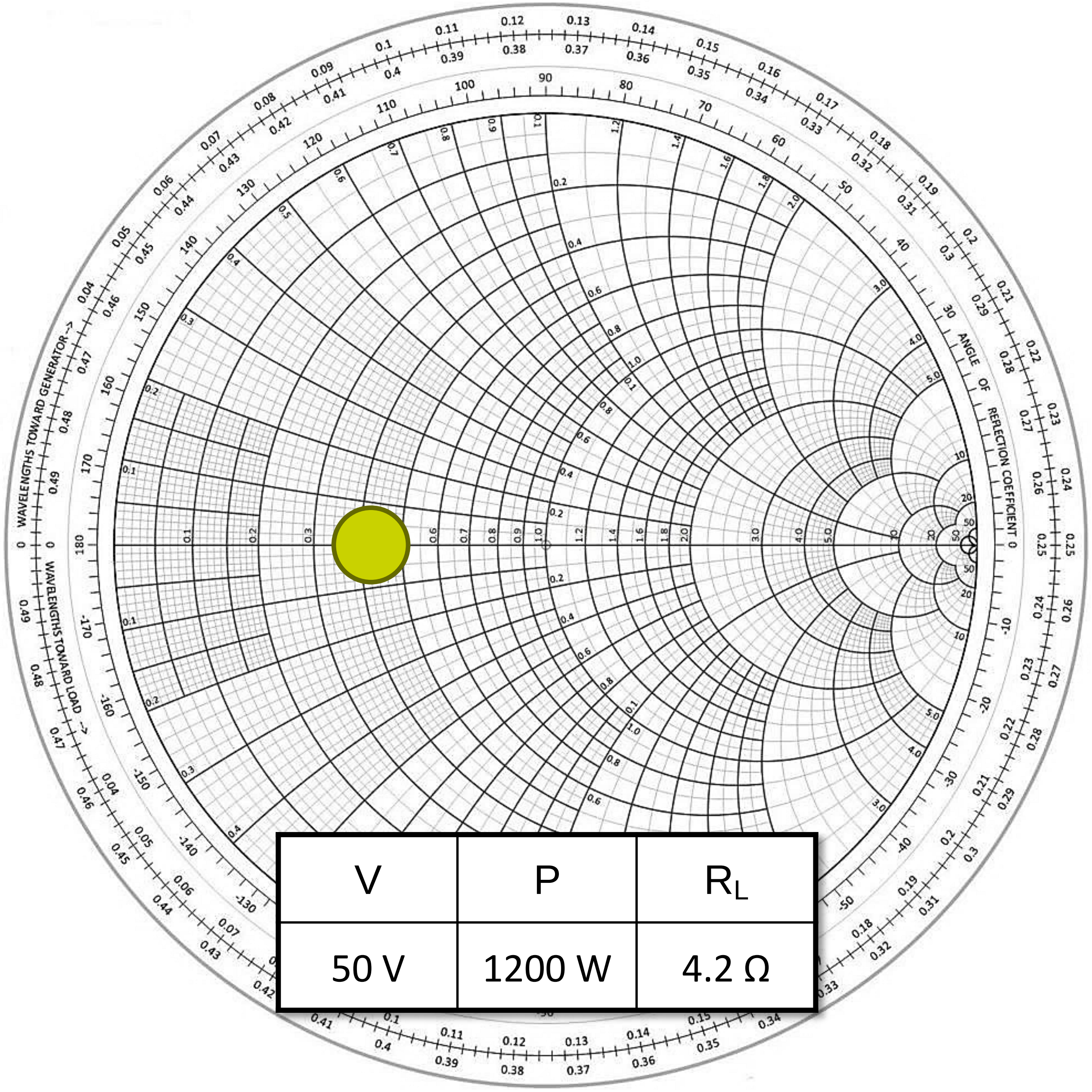
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1150 W	4.3 Ω

Higher output impedance

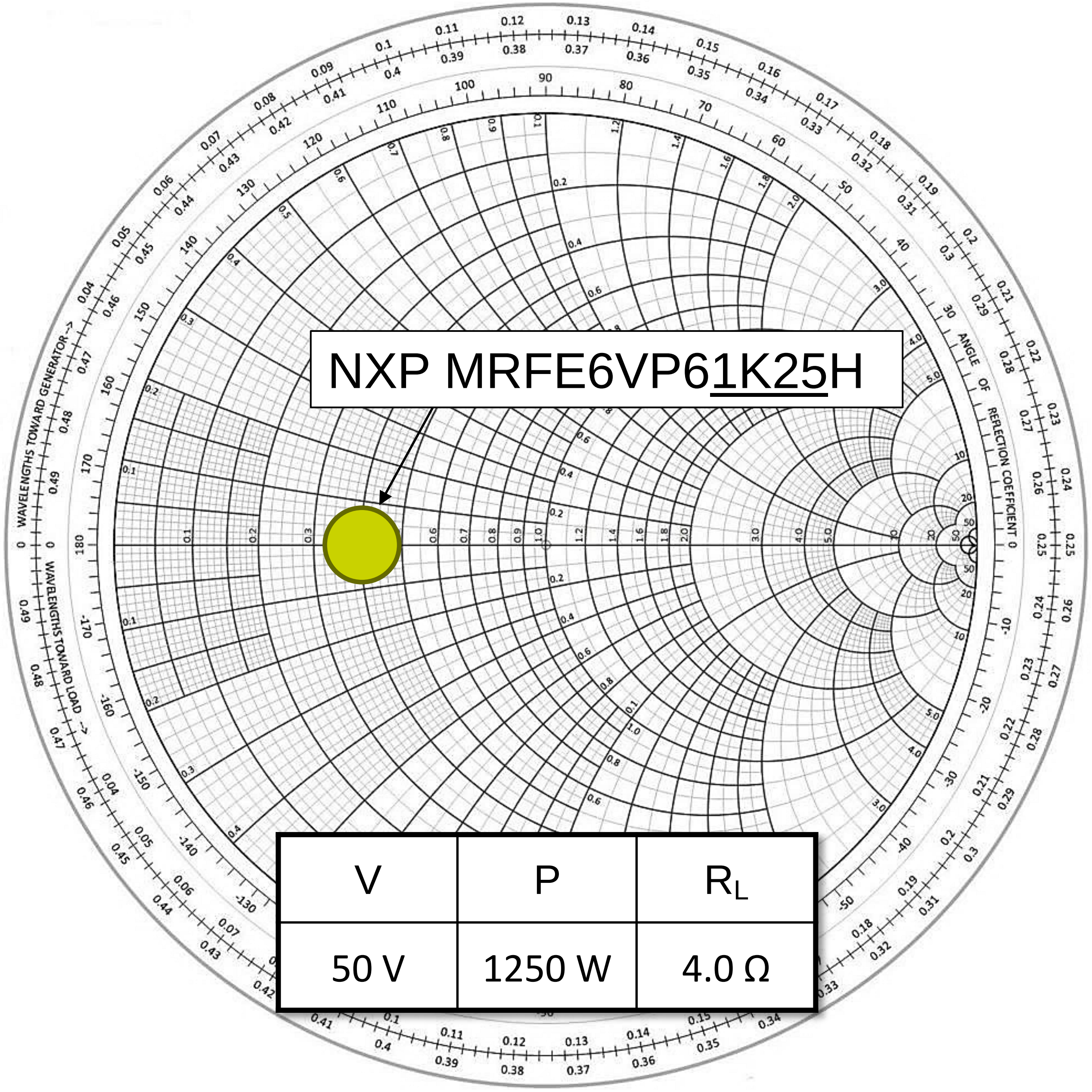
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1200 W	4.2 Ω

Higher output impedance

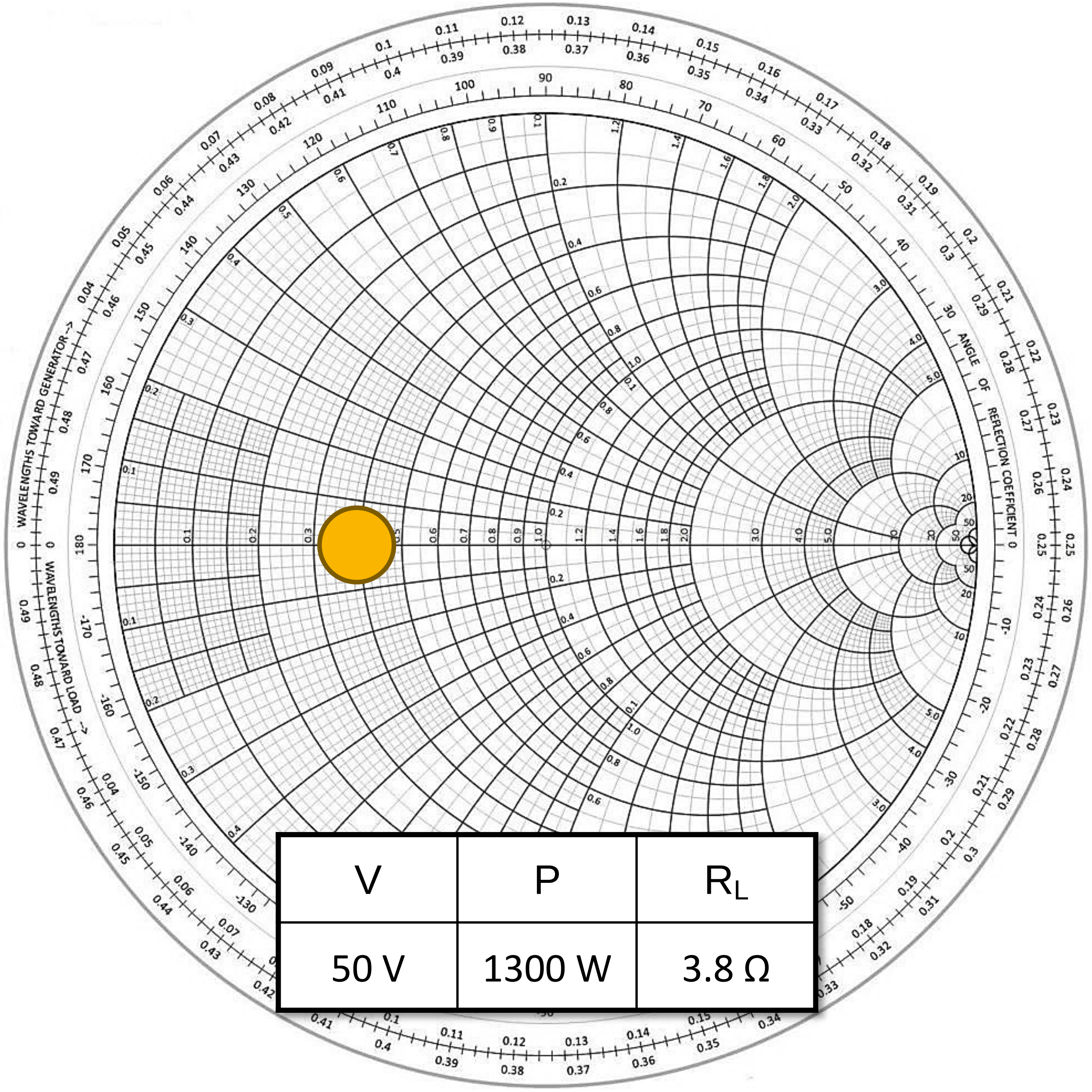
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1250 W	4.0 Ω

Higher output impedance

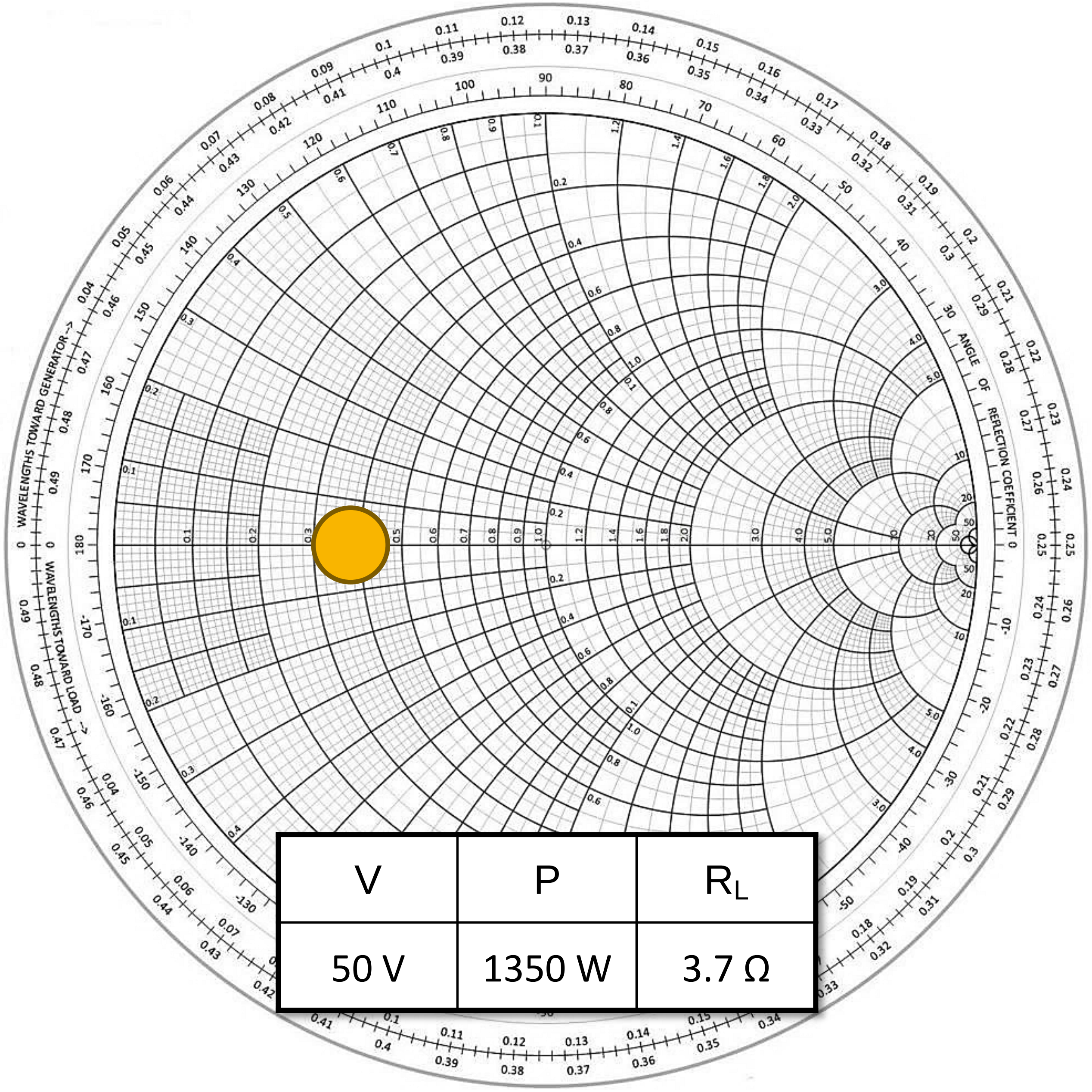
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1300 W	3.8 Ω

Higher output impedance

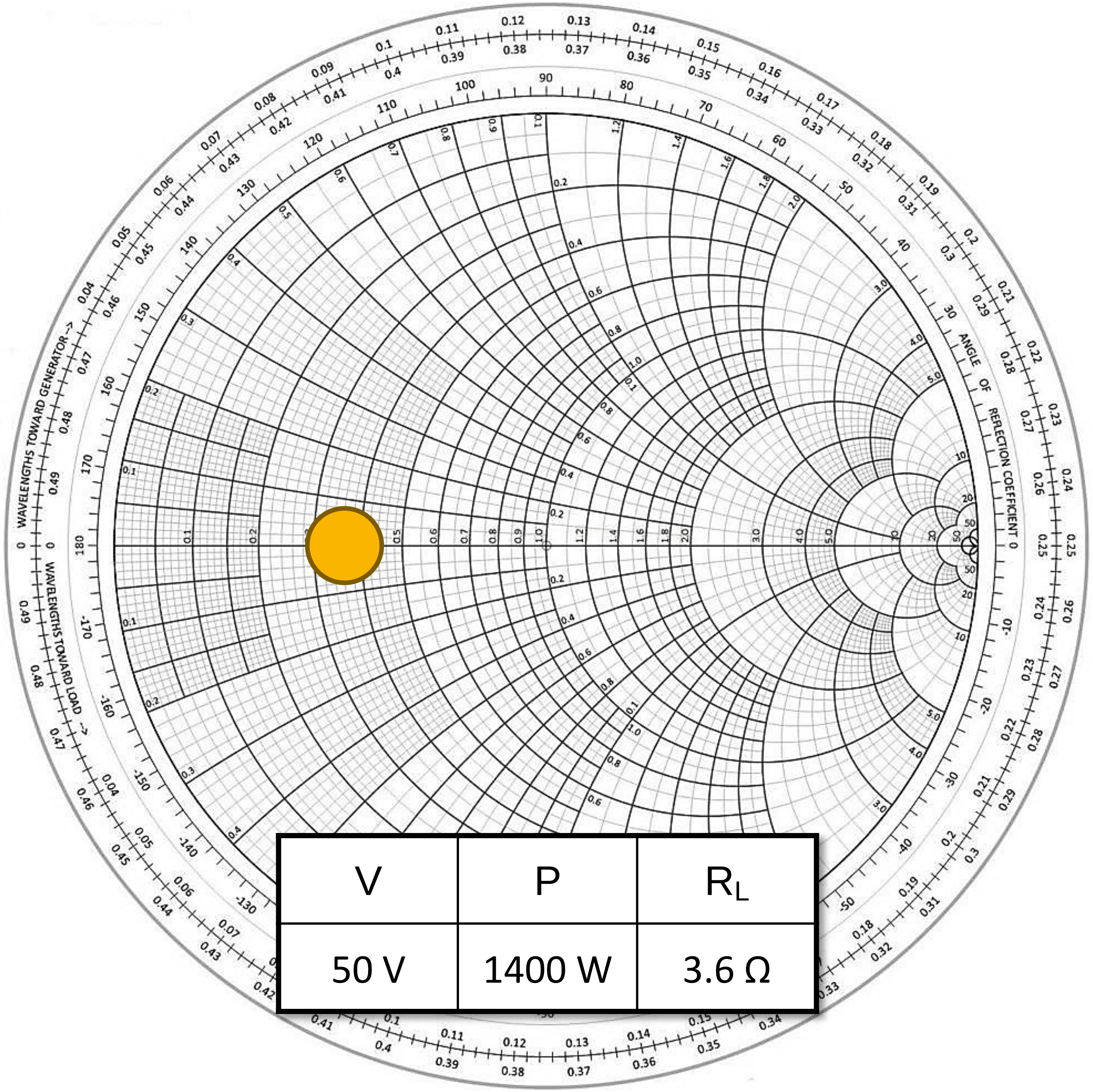
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1350 W	3.7 Ω

Higher output impedance

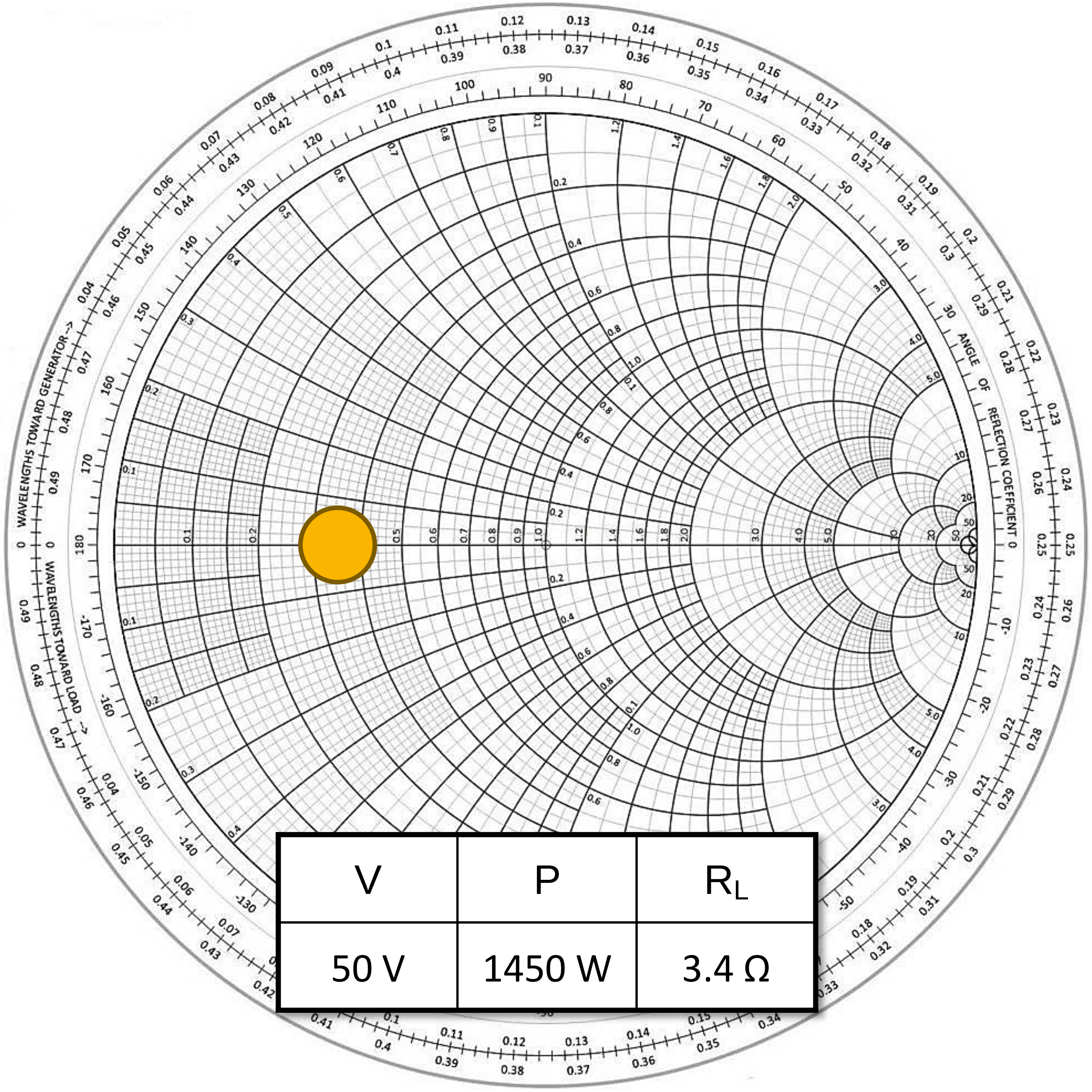
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1400 W	3.6 Ω

Higher output impedance

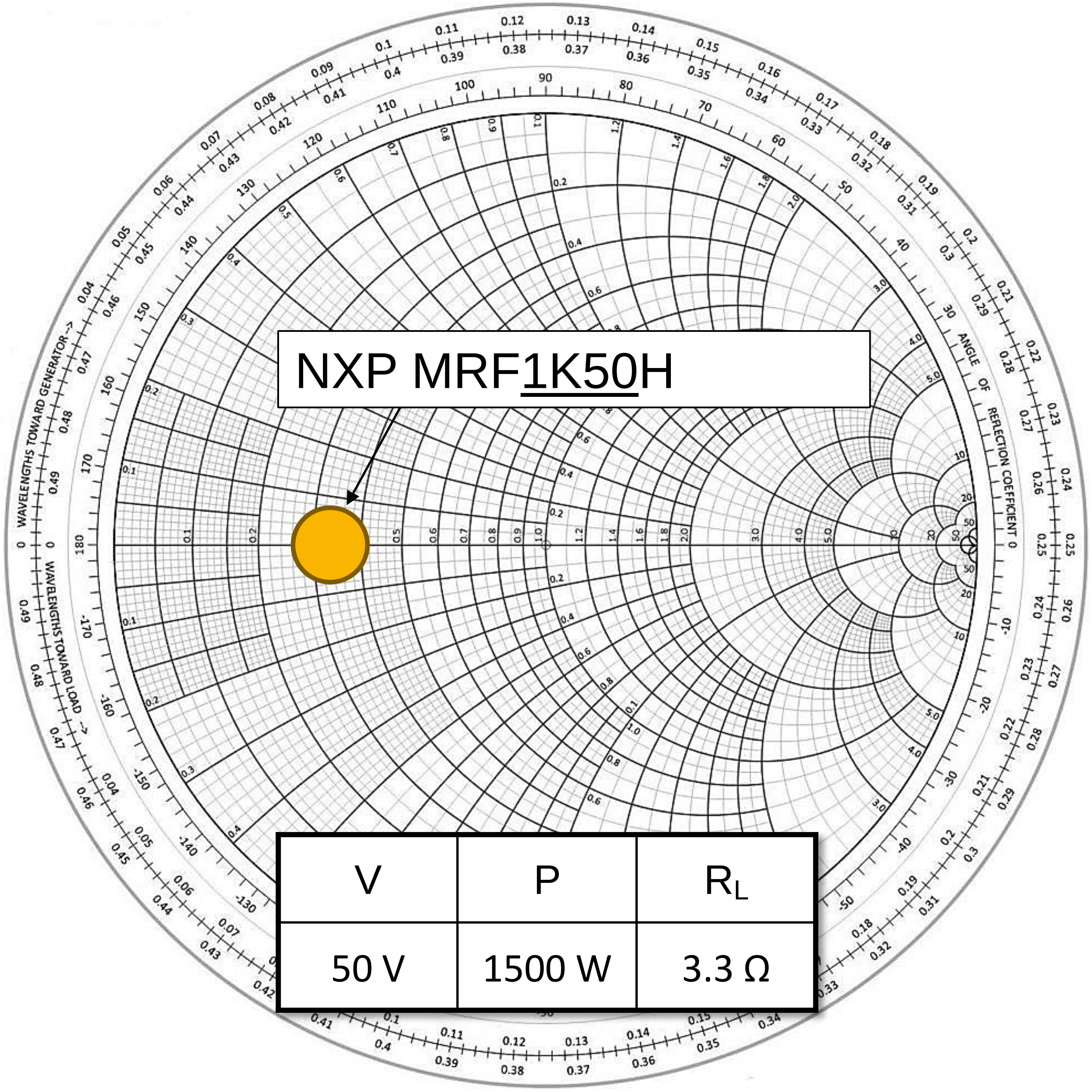
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1450 W	3.4 Ω

Higher output impedance

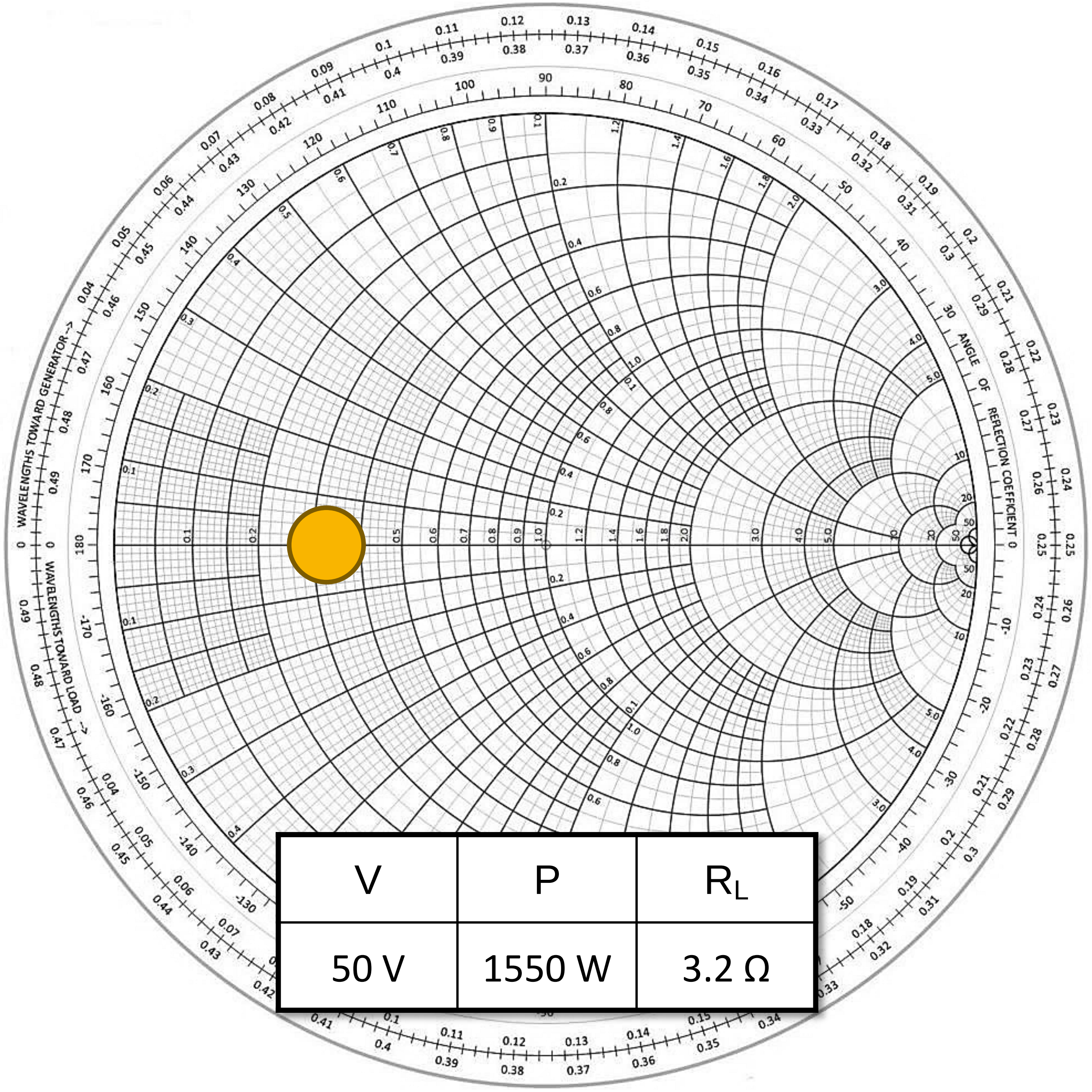
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1500 W	3.3 Ω

Higher output impedance

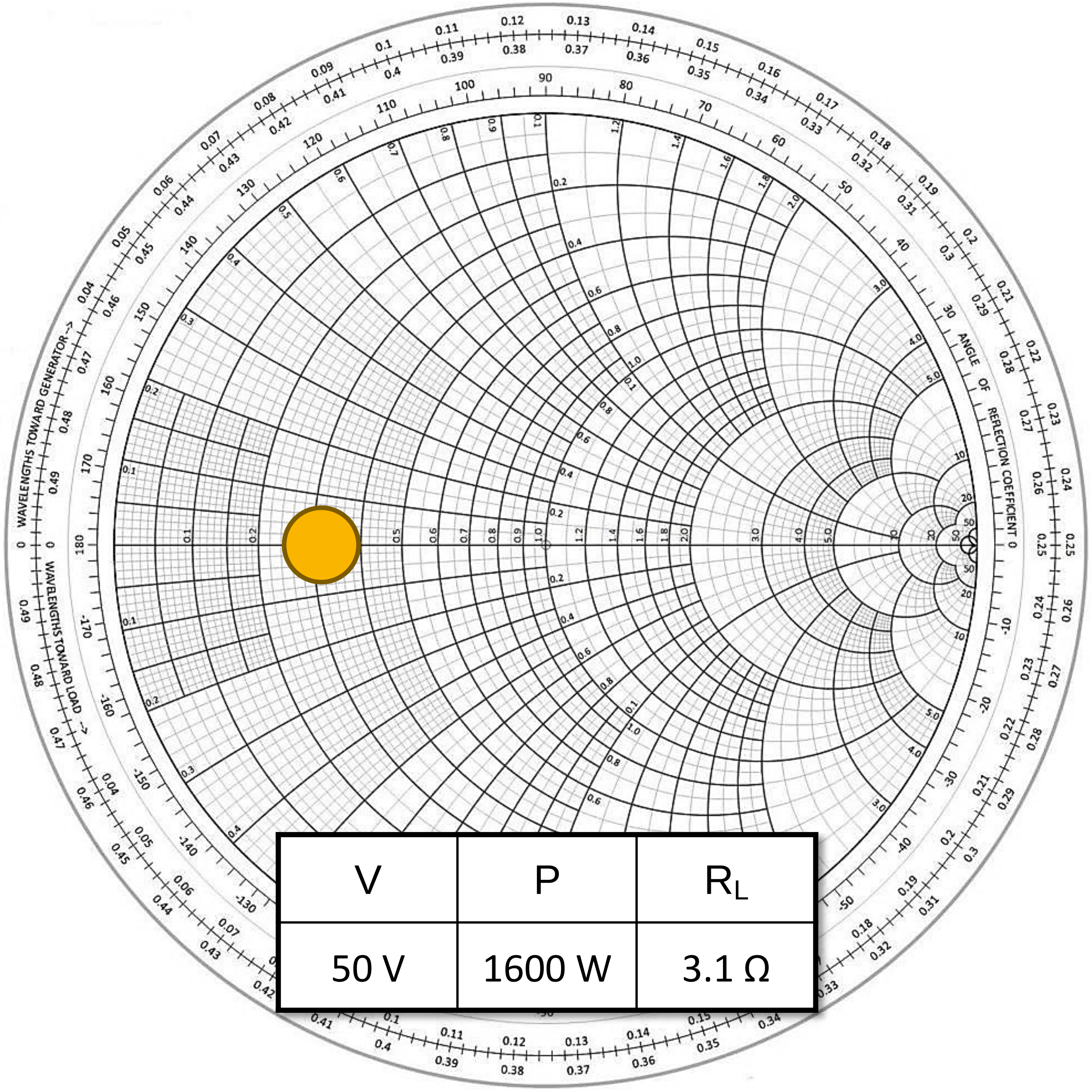
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1550 W	3.2 Ω

Higher output impedance

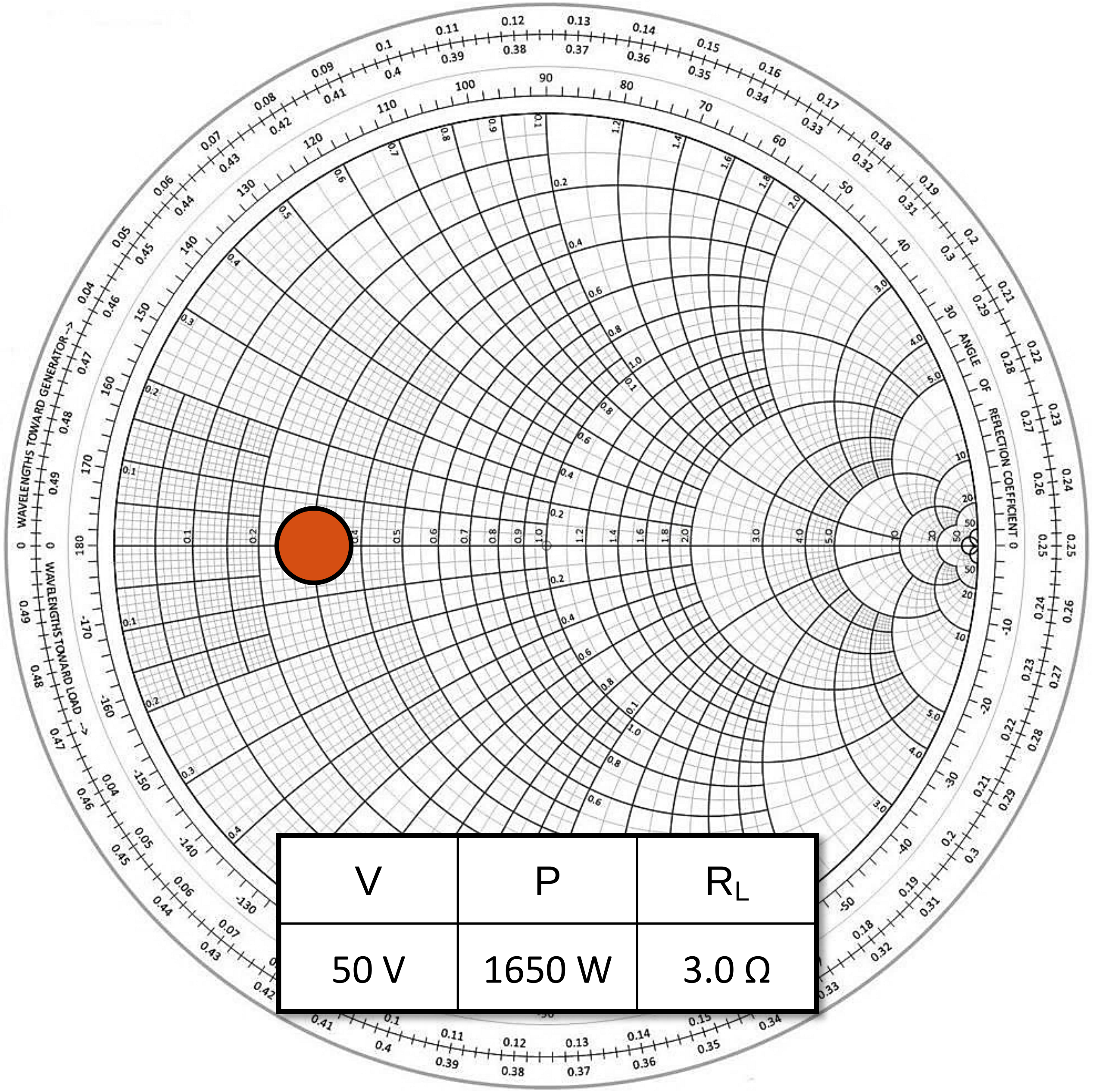
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1600 W	3.1 Ω

Higher output impedance

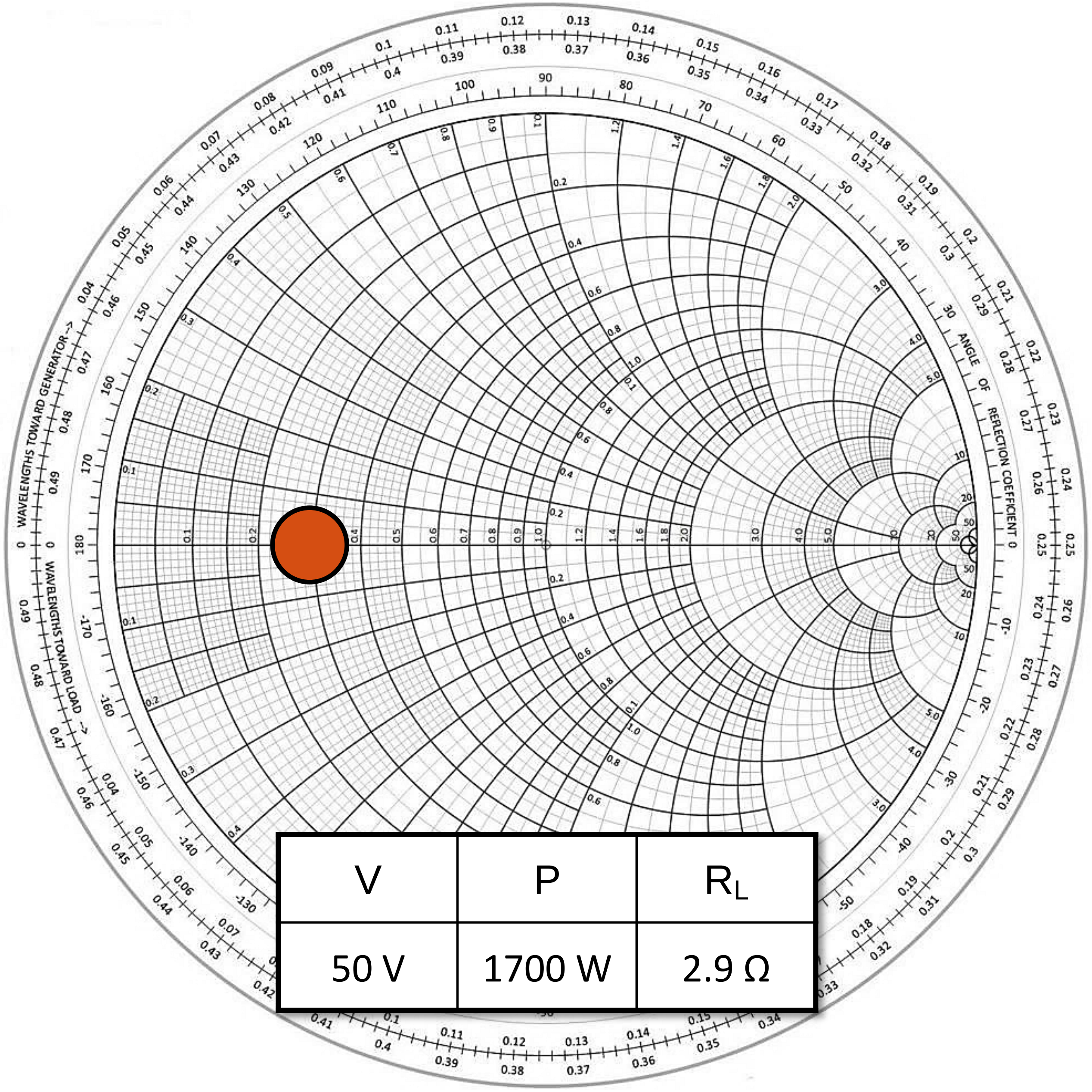
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1650 W	3.0 Ω

Higher output impedance

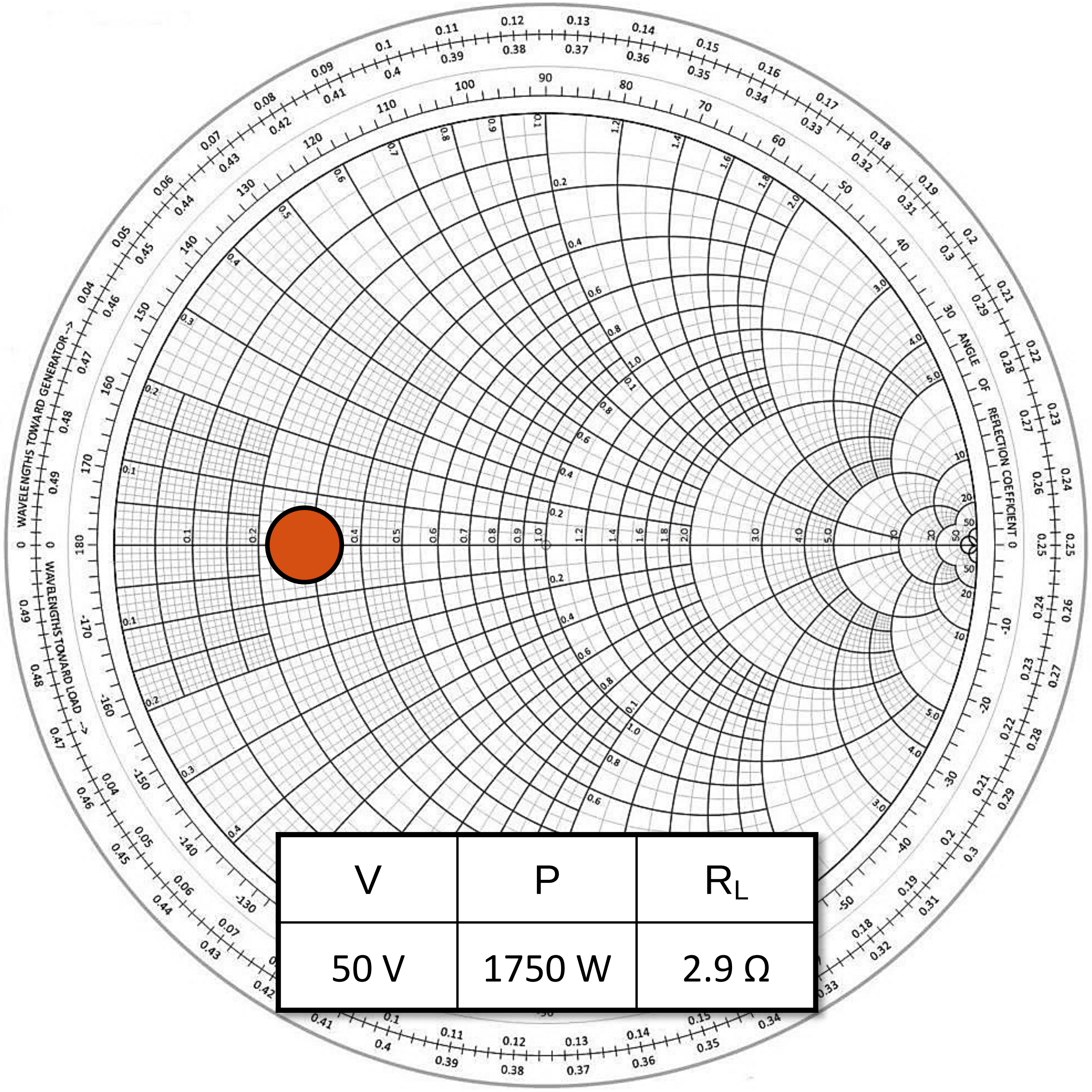
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1700 W	2.9 Ω

Higher output impedance

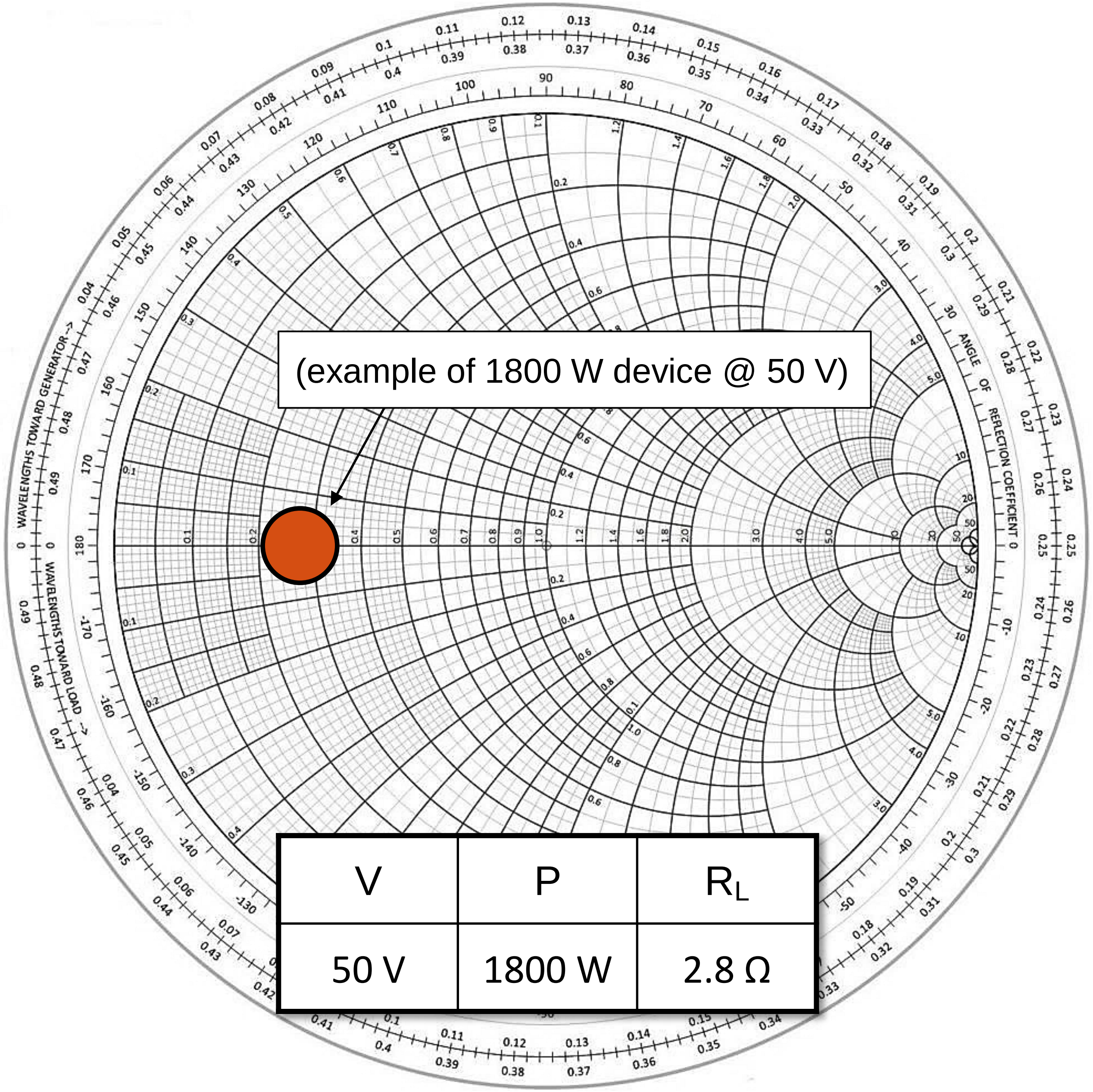
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1750 W	2.9 Ω

Higher output impedance

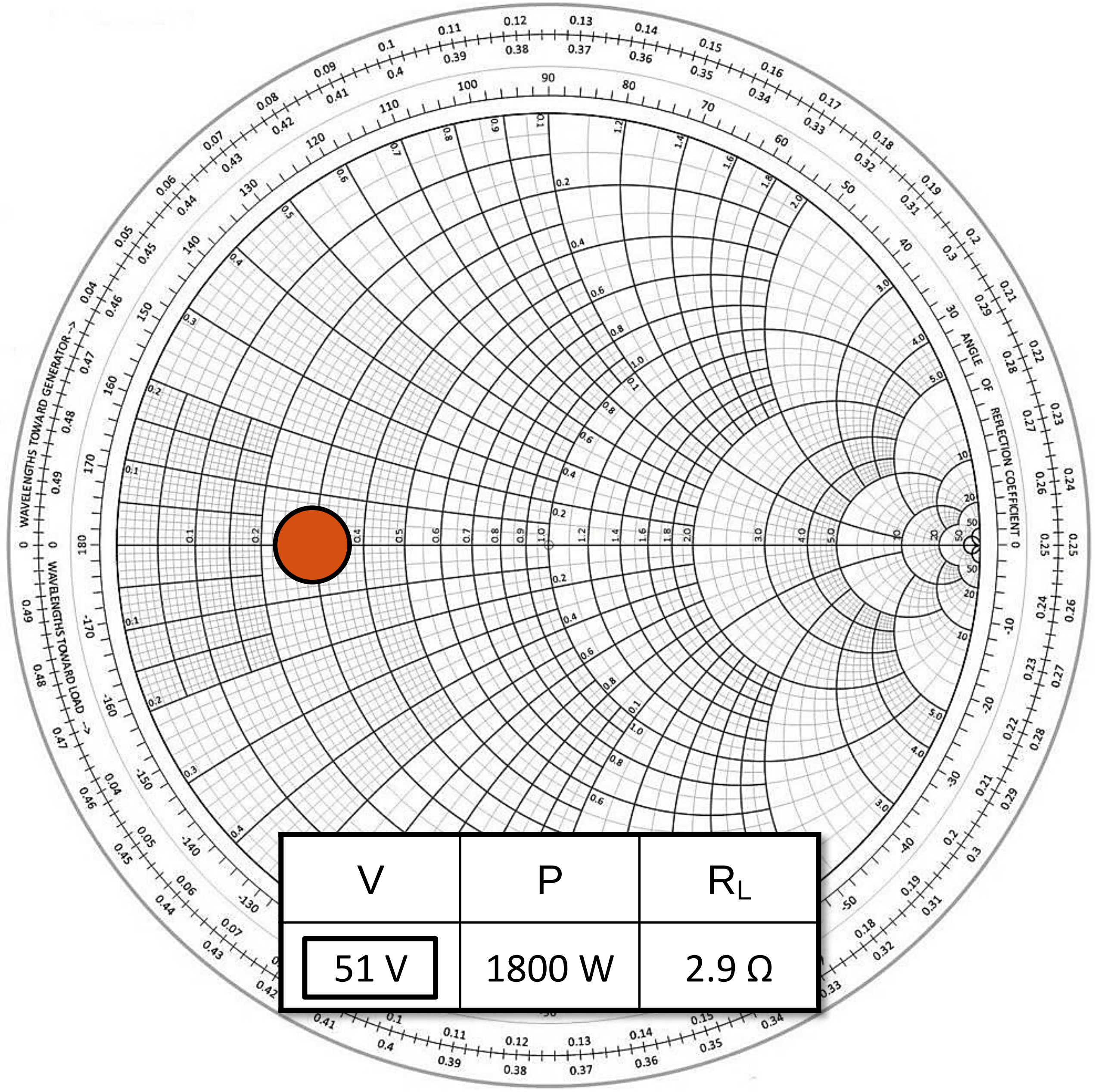
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
50 V	1800 W	2.8 Ω

Higher output impedance

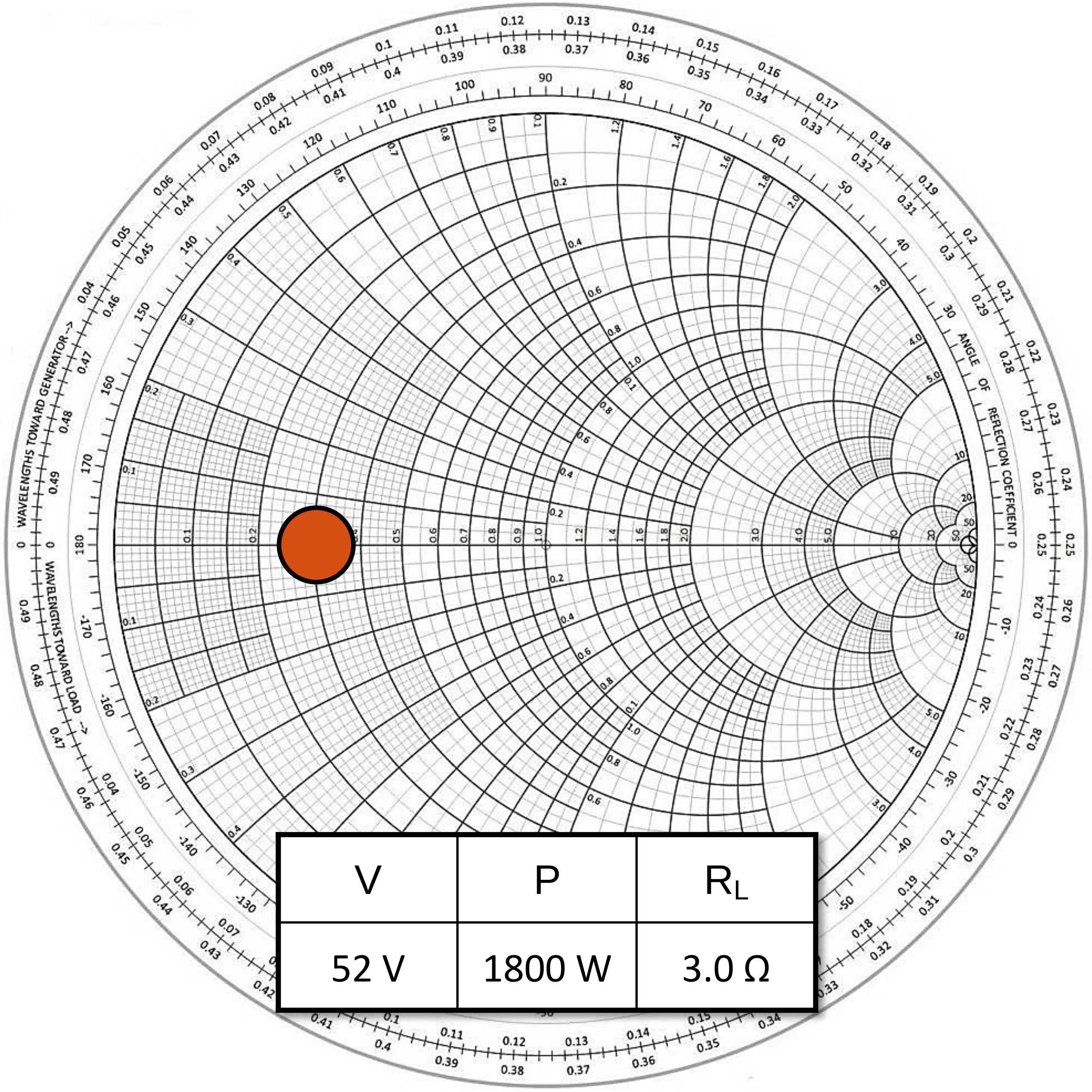
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
51 V	1800 W	2.9 Ω

Higher output impedance

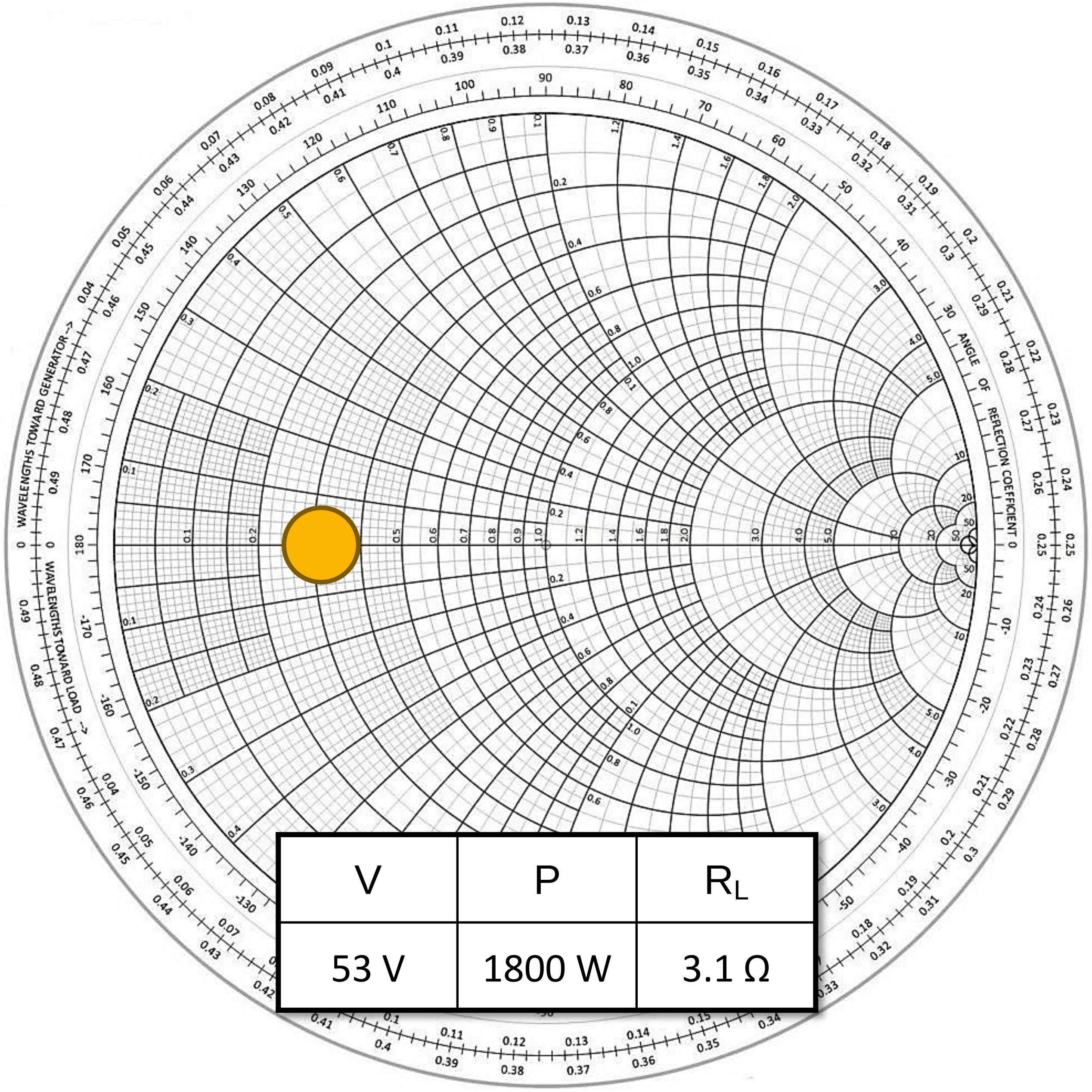
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
52 V	1800 W	3.0 Ω

Higher output impedance

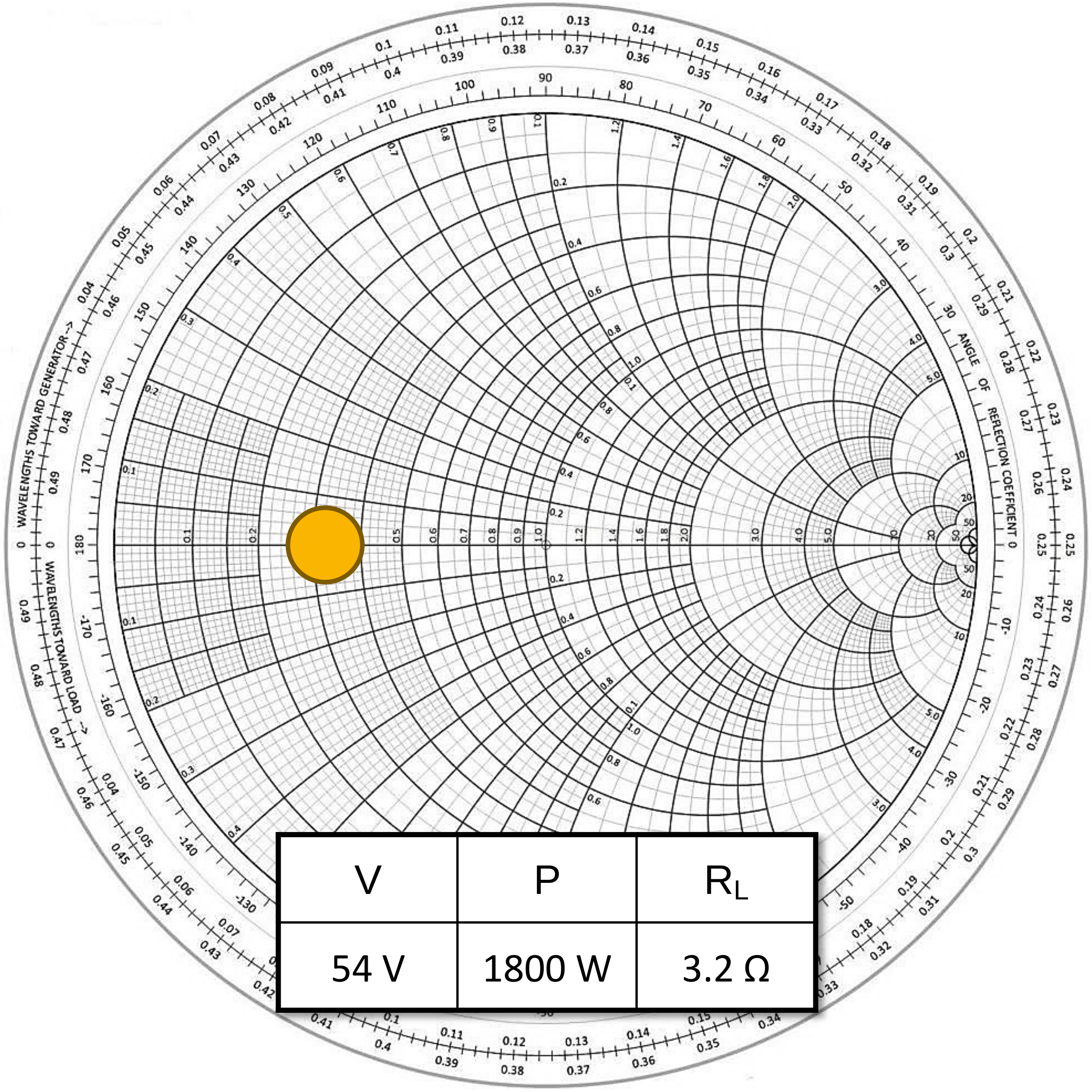
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
53 V	1800 W	3.1 Ω

Higher output impedance

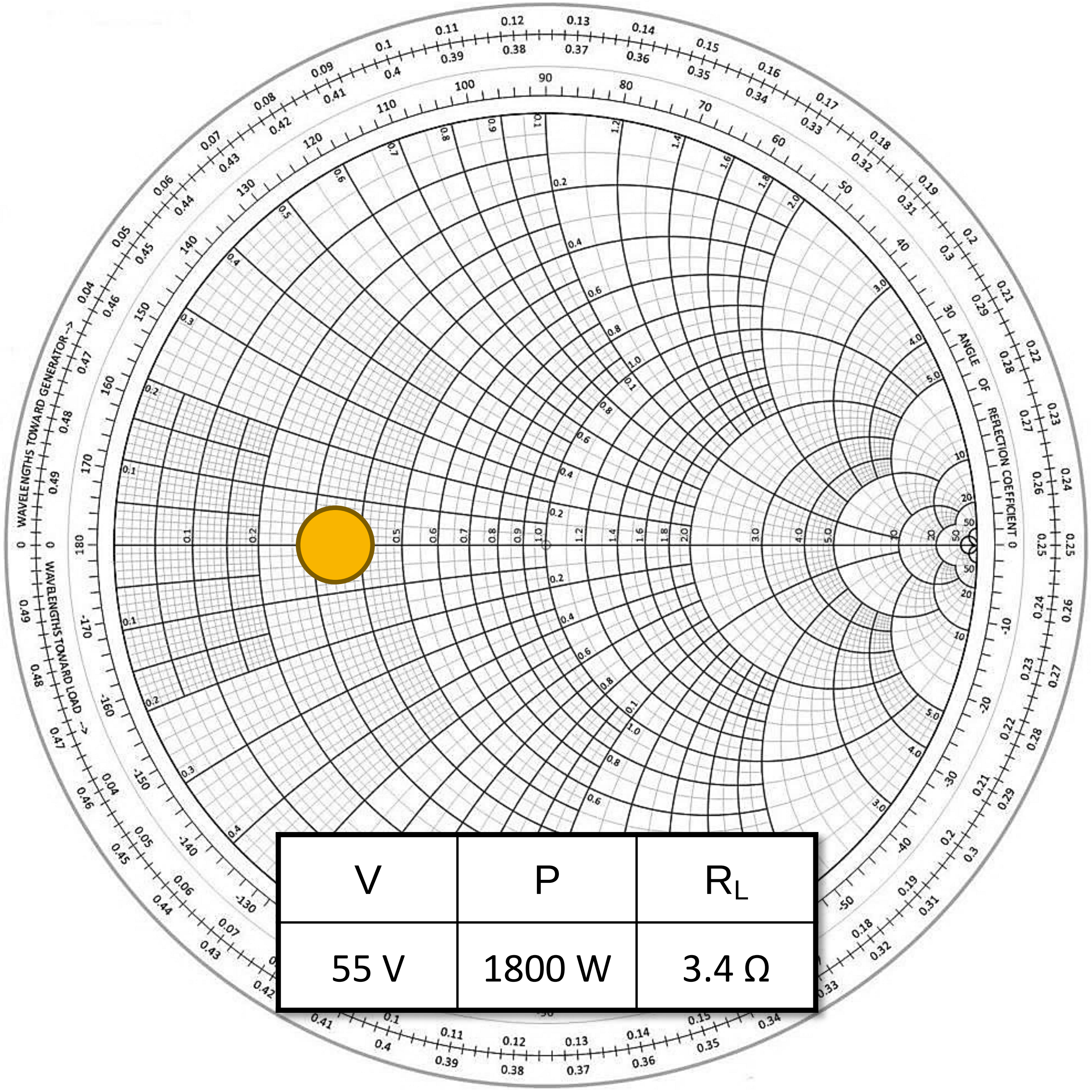
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
54 V	1800 W	3.2 Ω

Higher output impedance

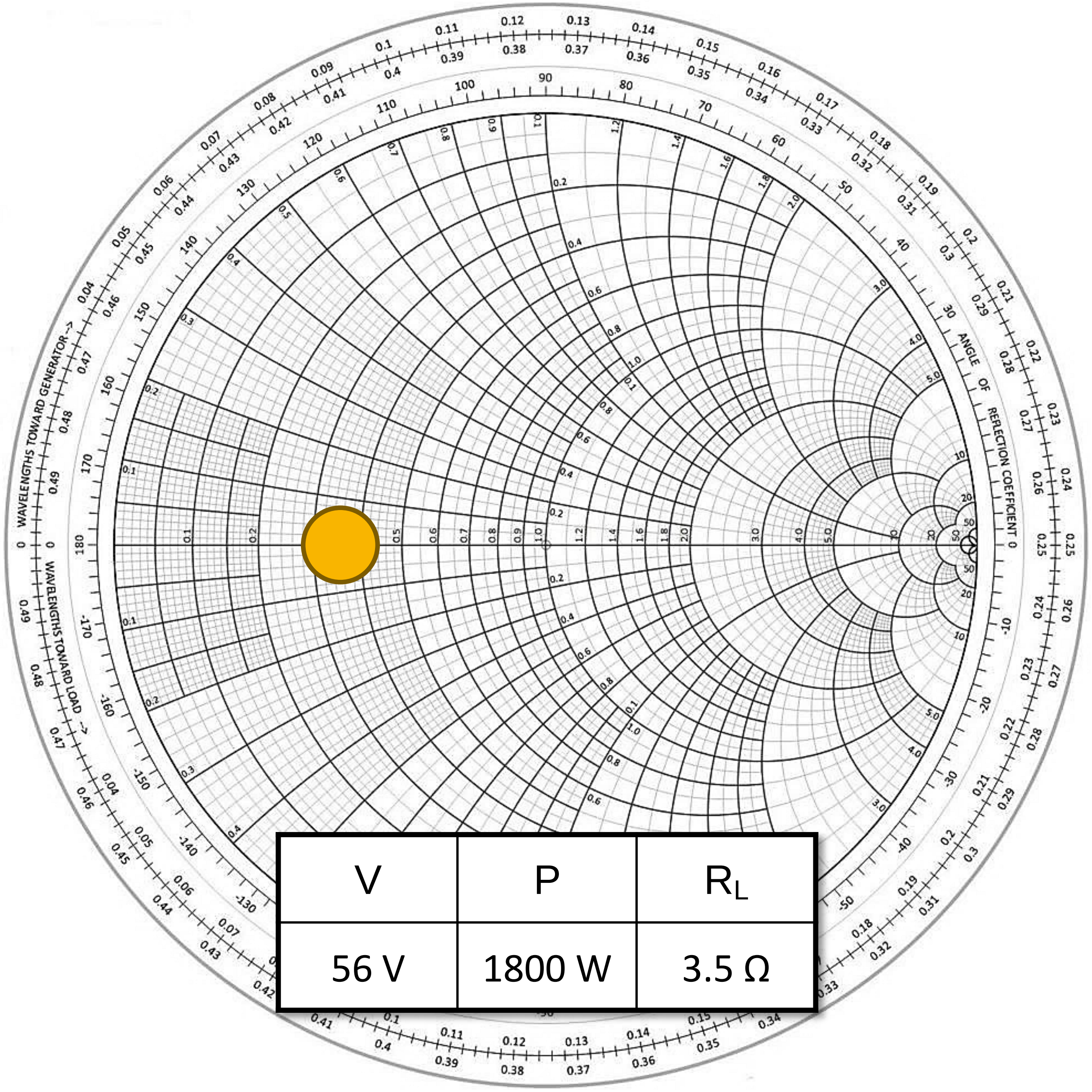
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
55 V	1800 W	3.4 Ω

Higher output impedance

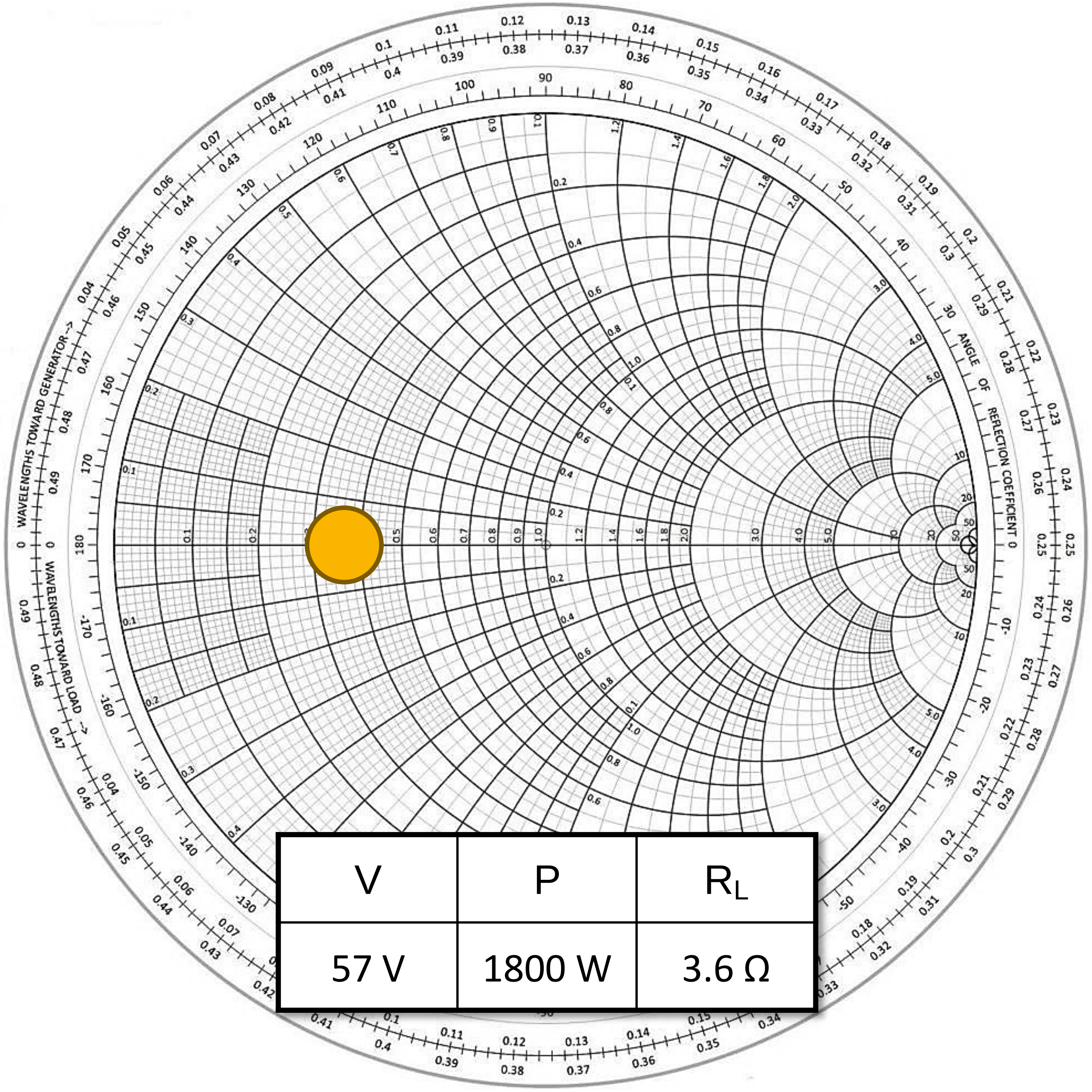
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
56 V	1800 W	3.5 Ω

Higher output impedance

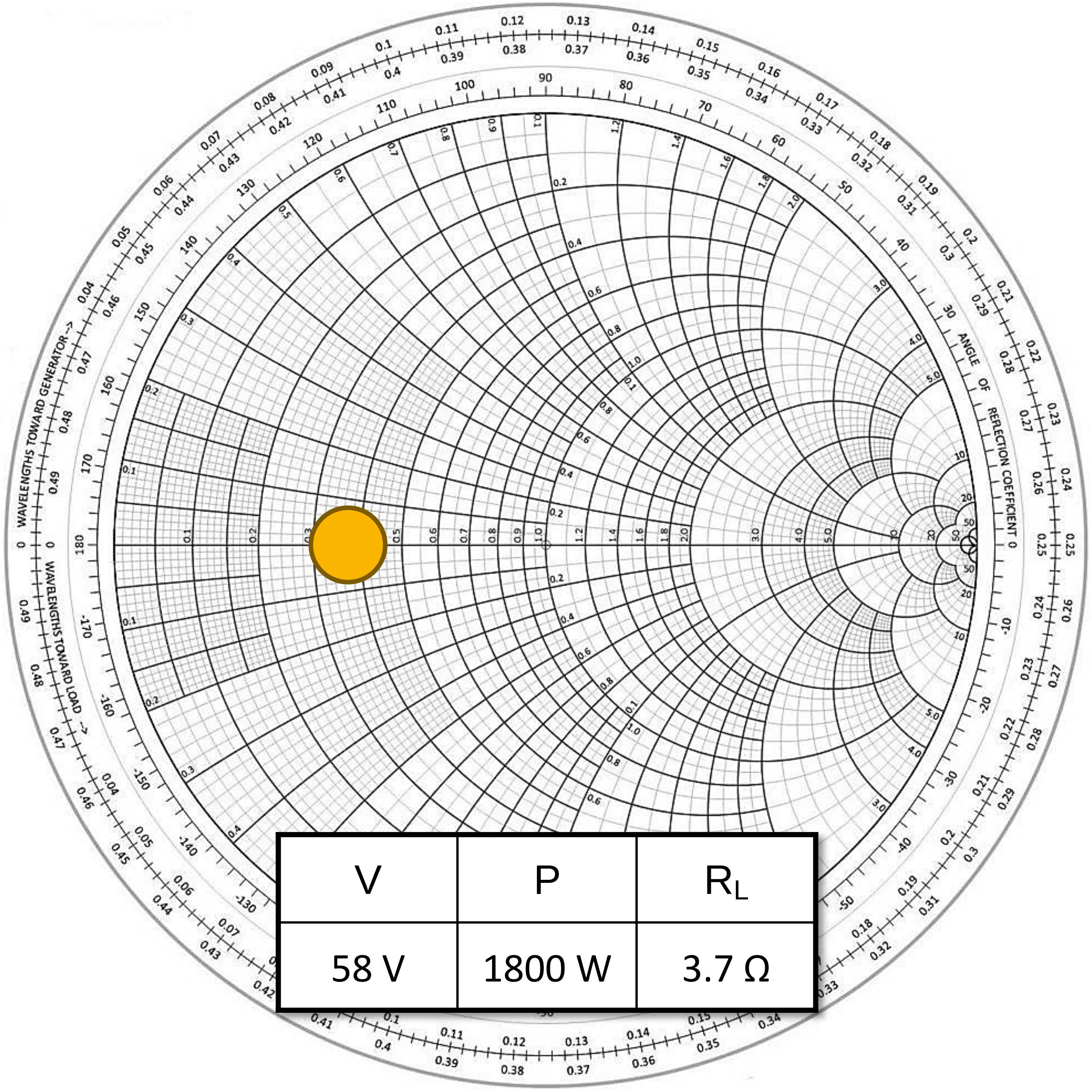
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
57 V	1800 W	3.6 Ω

Higher output impedance

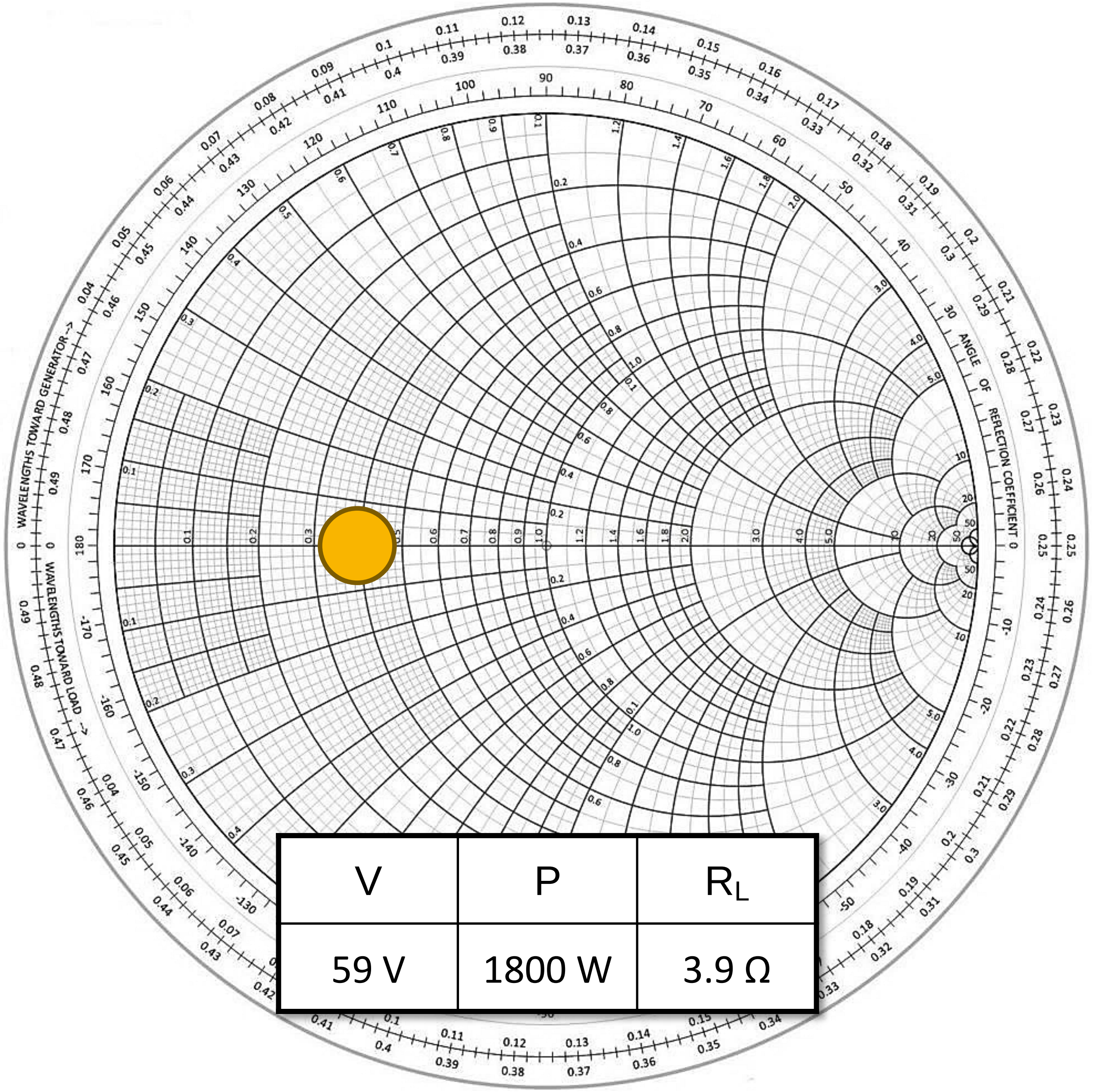
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
58 V	1800 W	3.7 Ω

Higher output impedance

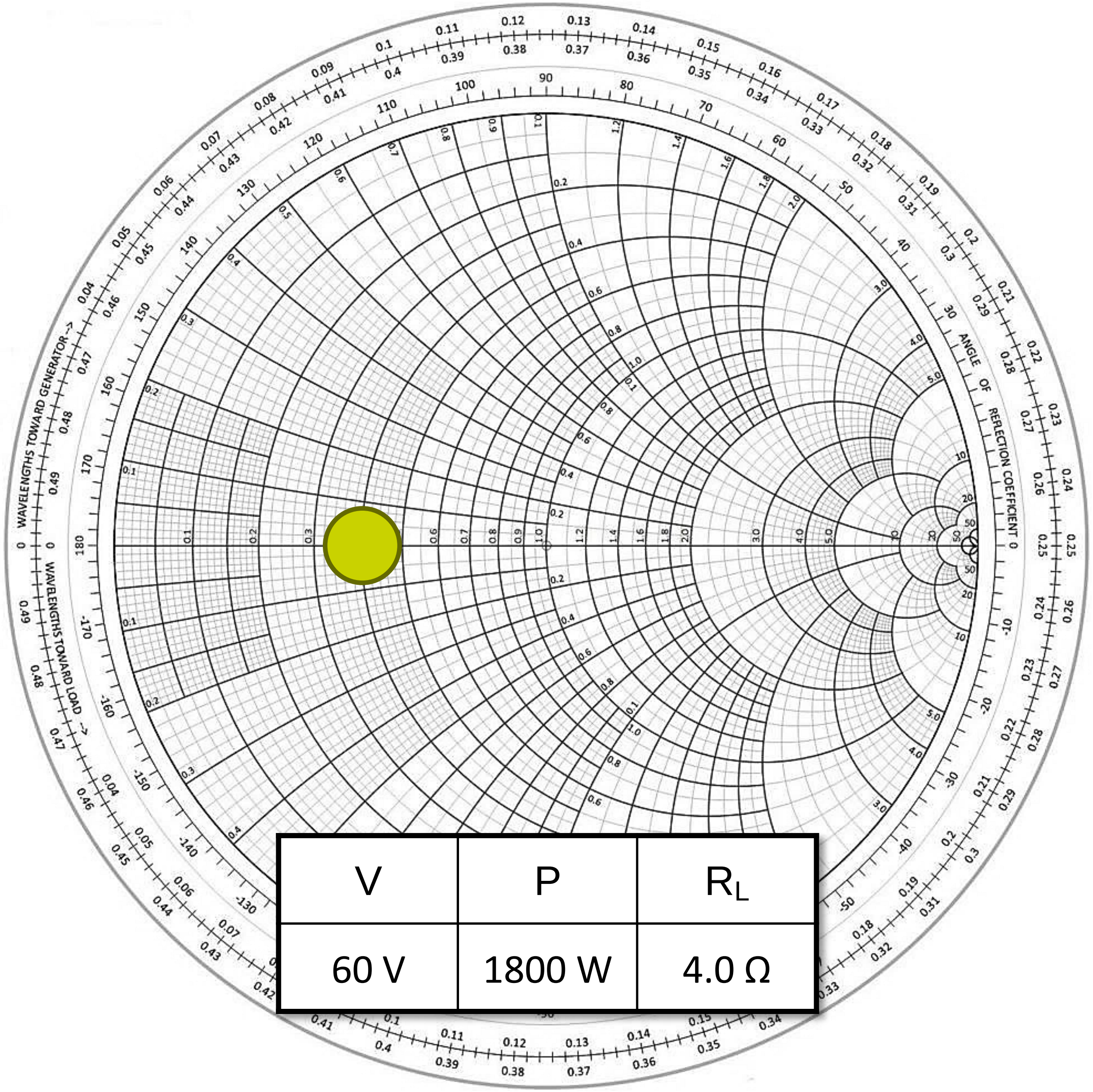
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
59 V	1800 W	3.9 Ω

Higher output impedance

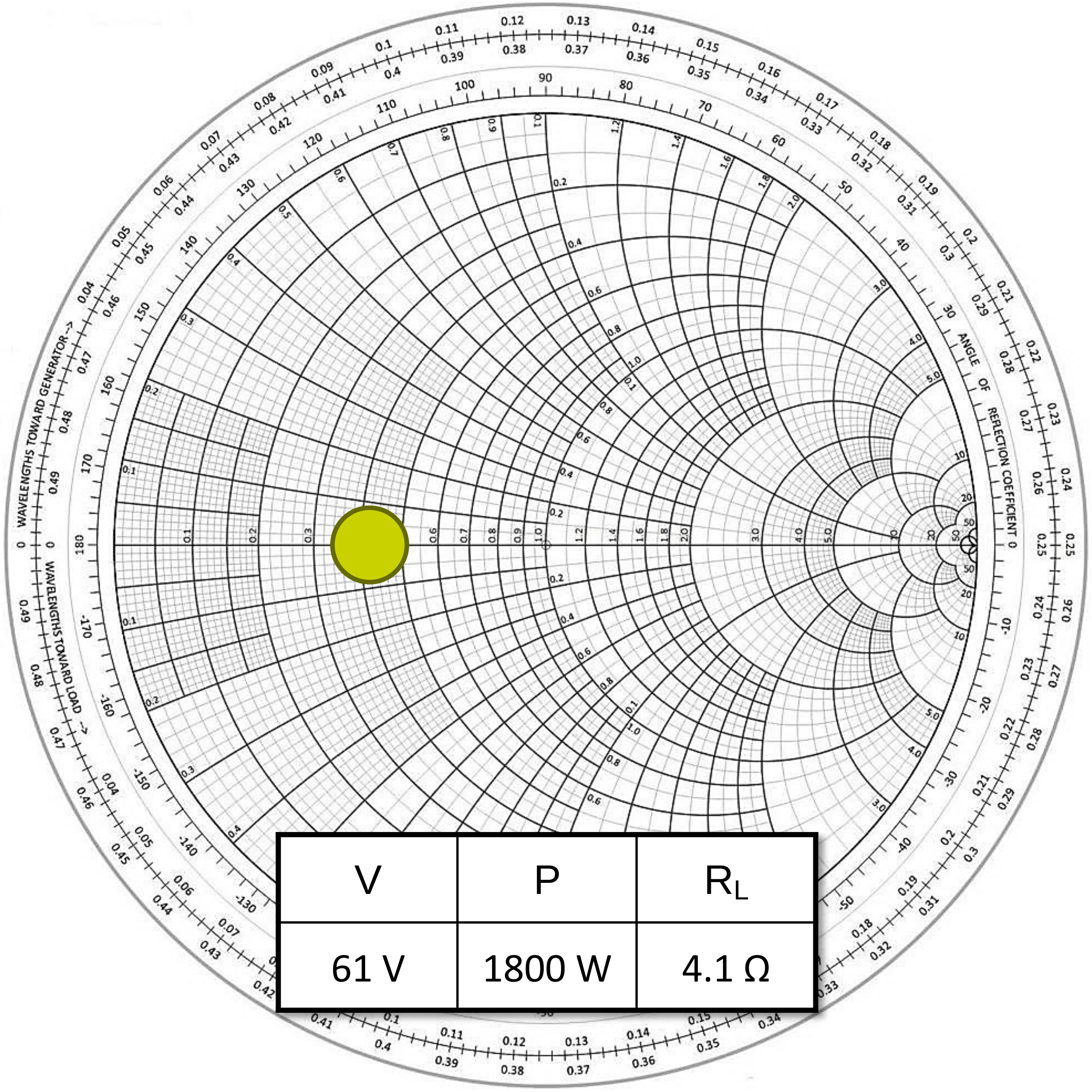
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
60 V	1800 W	4.0 Ω

Higher output impedance

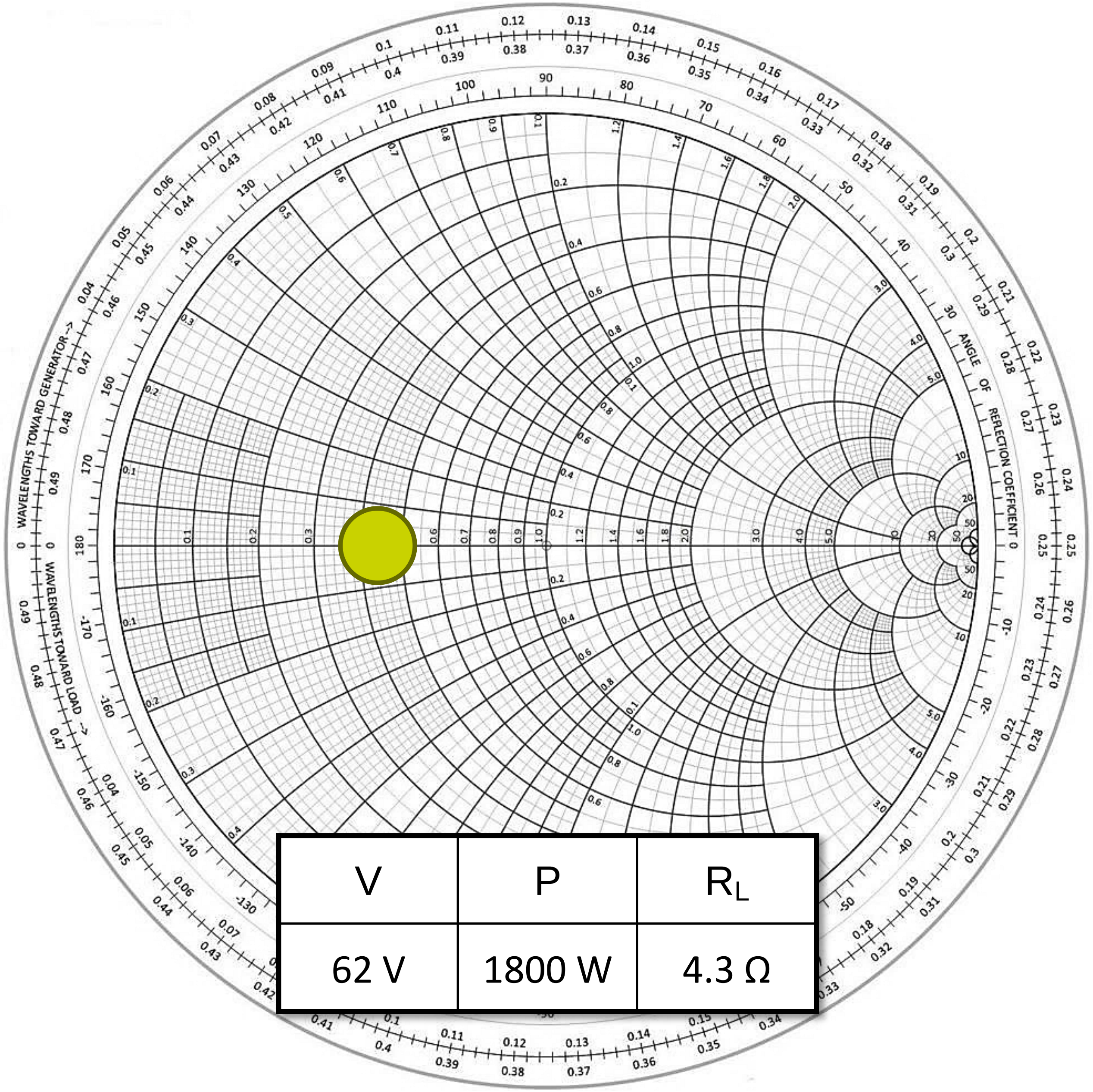
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
61 V	1800 W	4.1 Ω

Higher output impedance

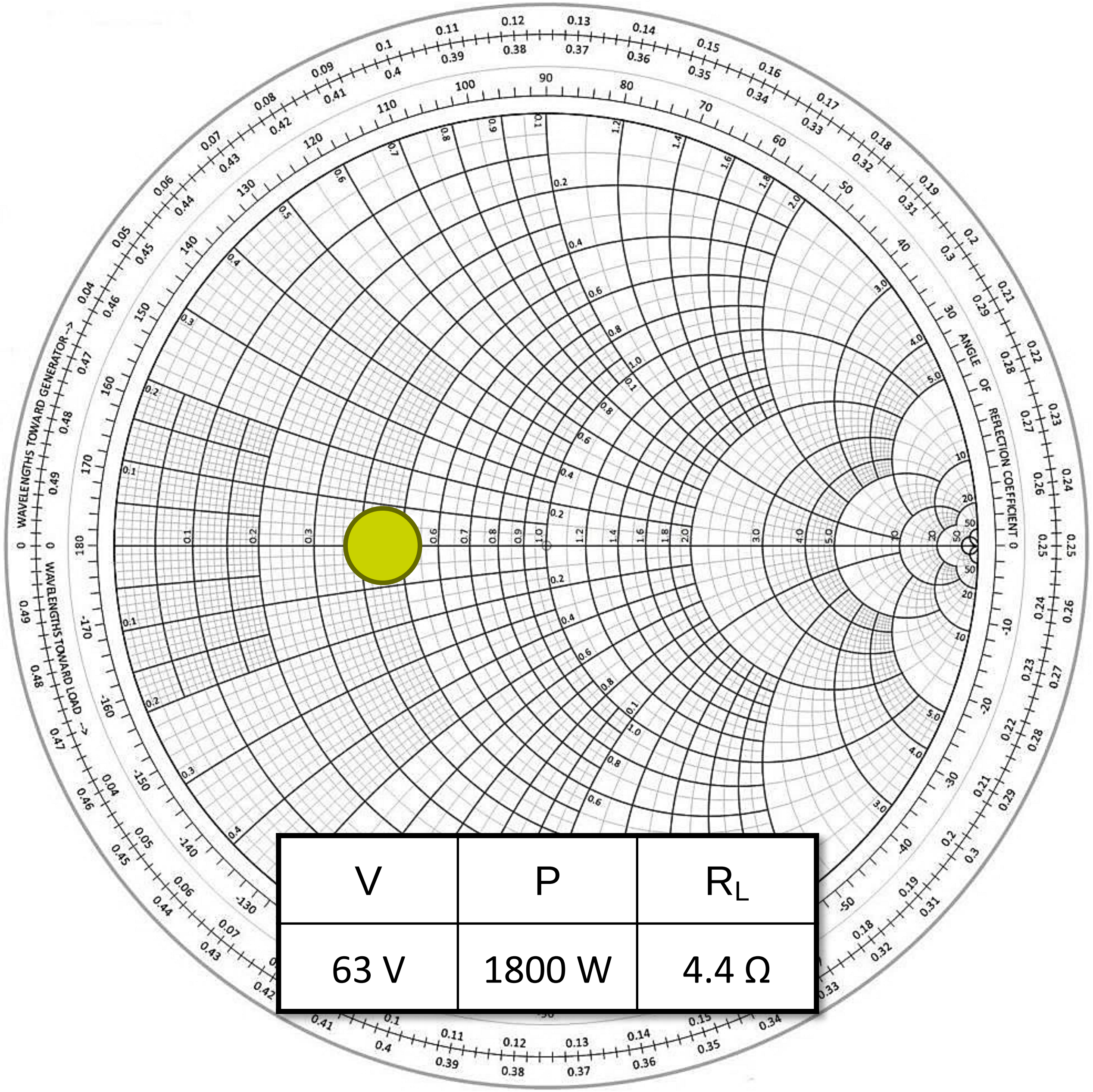
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
62 V	1800 W	4.3 Ω

Higher output impedance

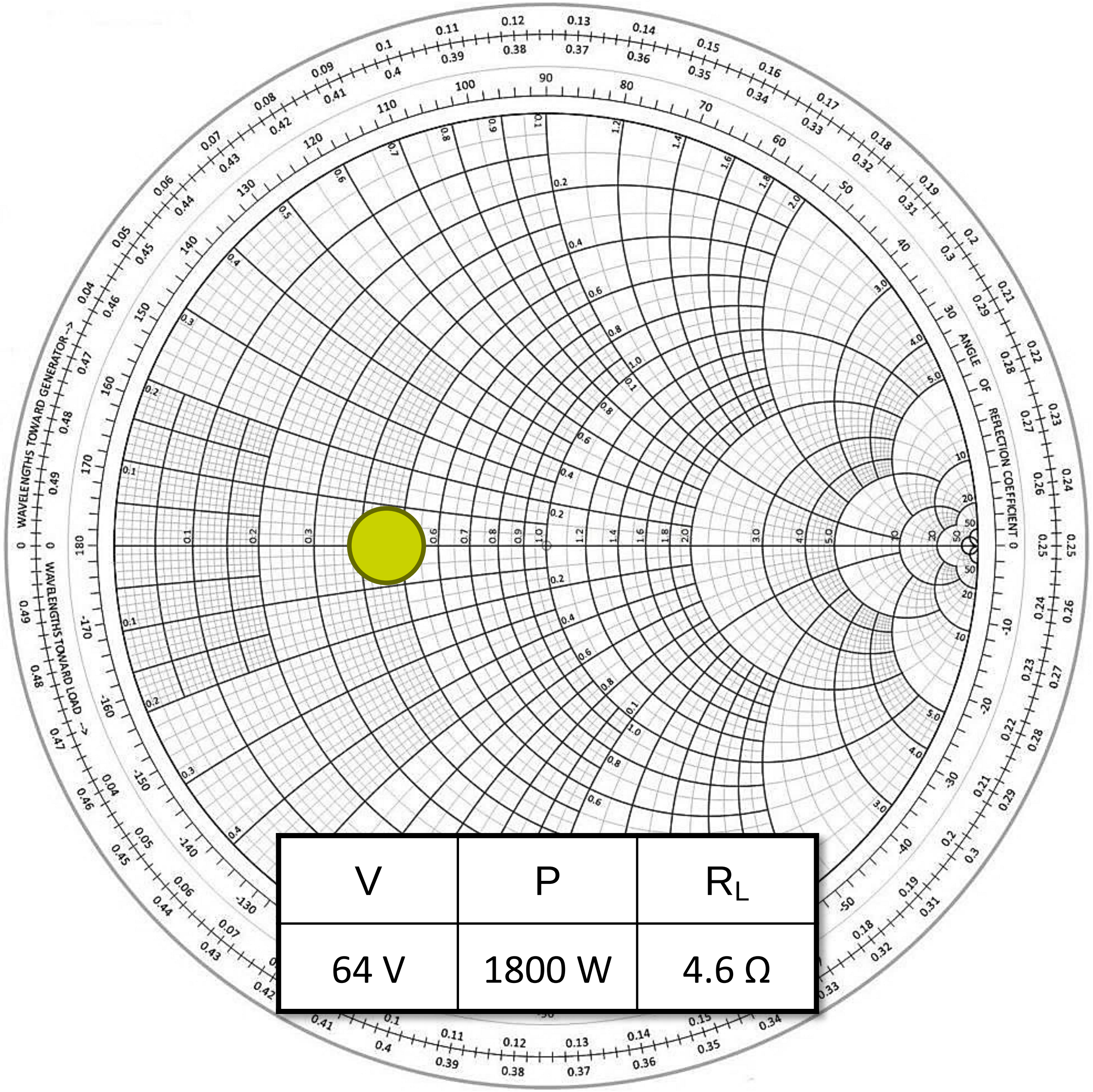
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
63 V	1800 W	4.4 Ω

Higher output impedance

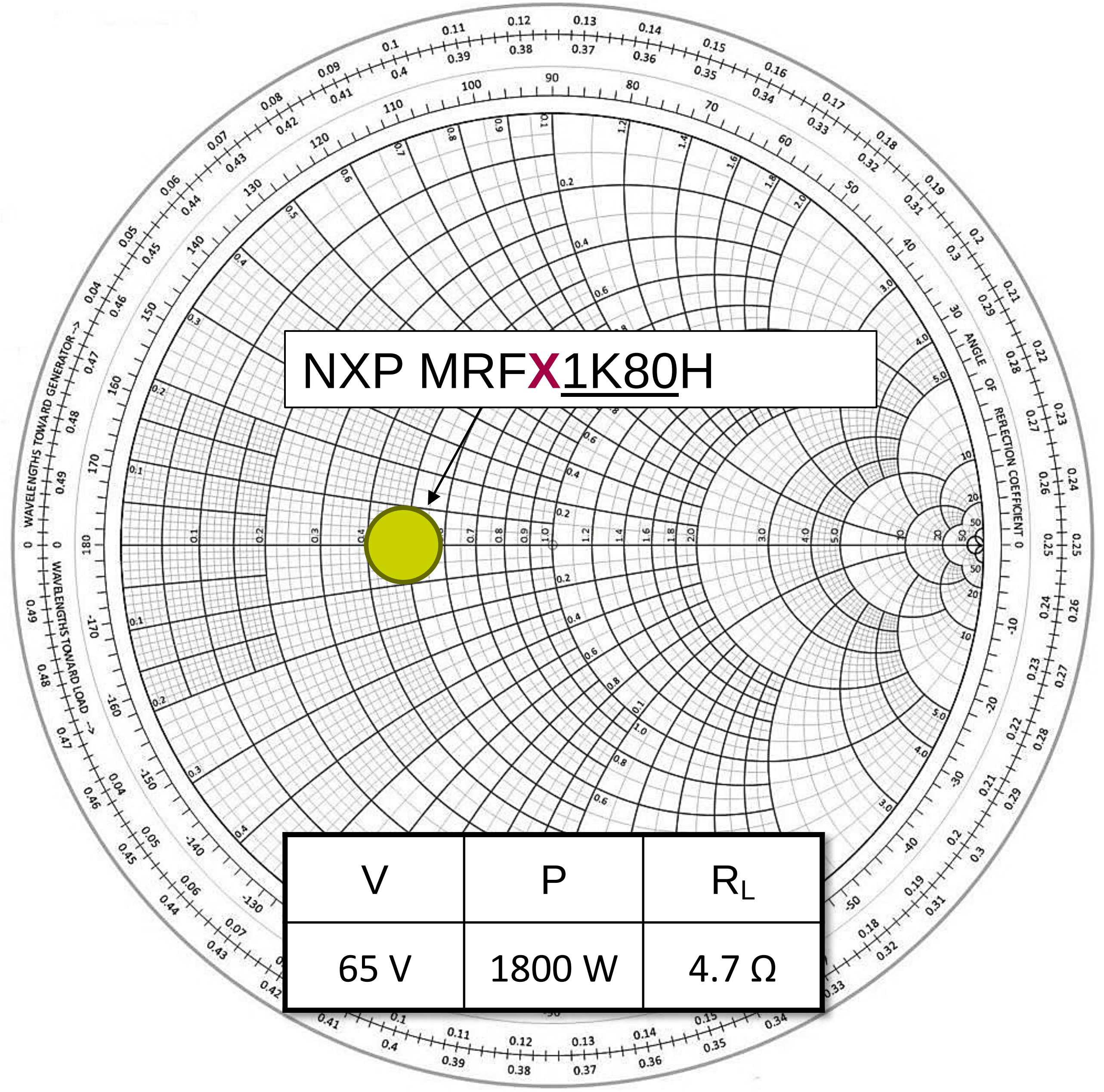
$$R_L = \frac{V^2}{2P}$$



V	P	R_L
64 V	1800 W	4.6 Ω

Higher output impedance

$$R_L = \frac{V^2}{2P}$$



V	P	R_L
65 V	1800 W	4.7 Ω

Summary: 65 V enables matching ease of use

	MRFE6VP 61K25H	MRF1K50H	MRFX1K80H
Output impedance in HF in push-pull configuration **R_L** (transformation ratio to 50 ohm)	4.0 ohm (x12.5)	3.3 ohm (x15)	4.7 ohm (x10)
Output capacitance **Coss**	185pF	205pF	203pF

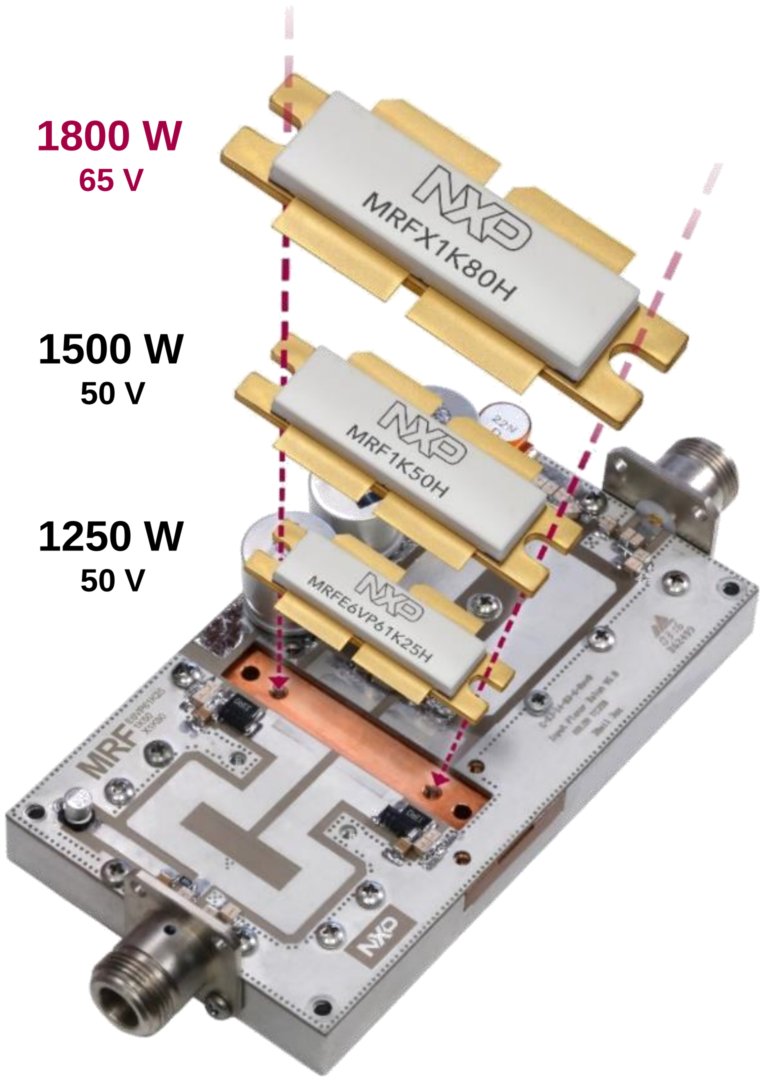
For a given technology, adding more LDMOS periphery adds more Coss. A higher Coss lowers the output impedance in high frequency.

Close output impedances help **reuse** the same matching circuit.

NXP RF Transistor Design Strategy: Focus on Scalability

Transistors from the MRFX series fit into existing PCBs designed for previous NXP transistors

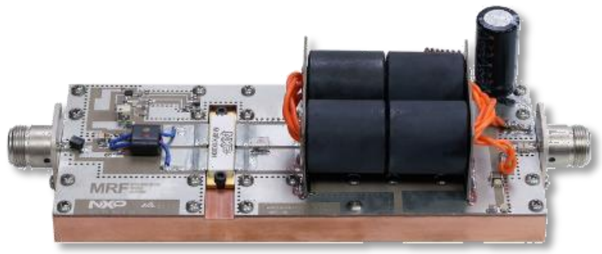
- Same PCB for MRFE6VP61K25H, MRE6VP61K25N, MRF1K50H, MRF1K50N, MRFX1K80H, MRFX1K80N
- Little to no retuning needed

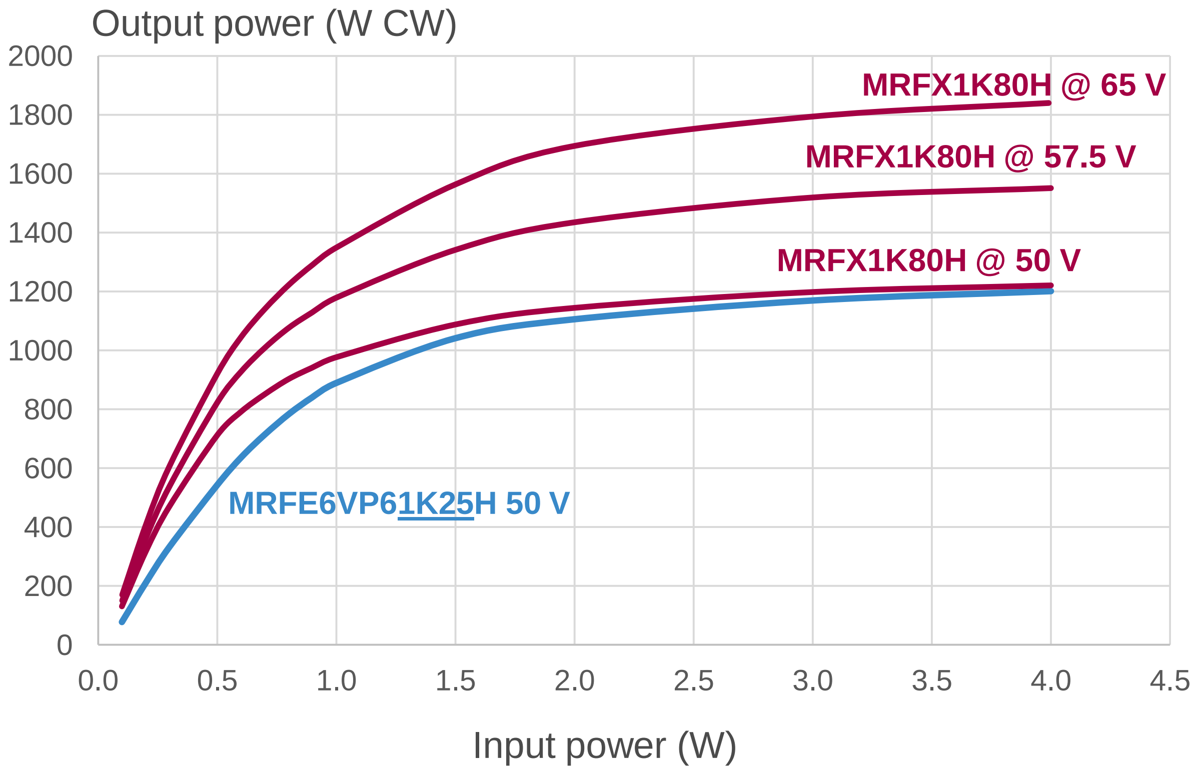


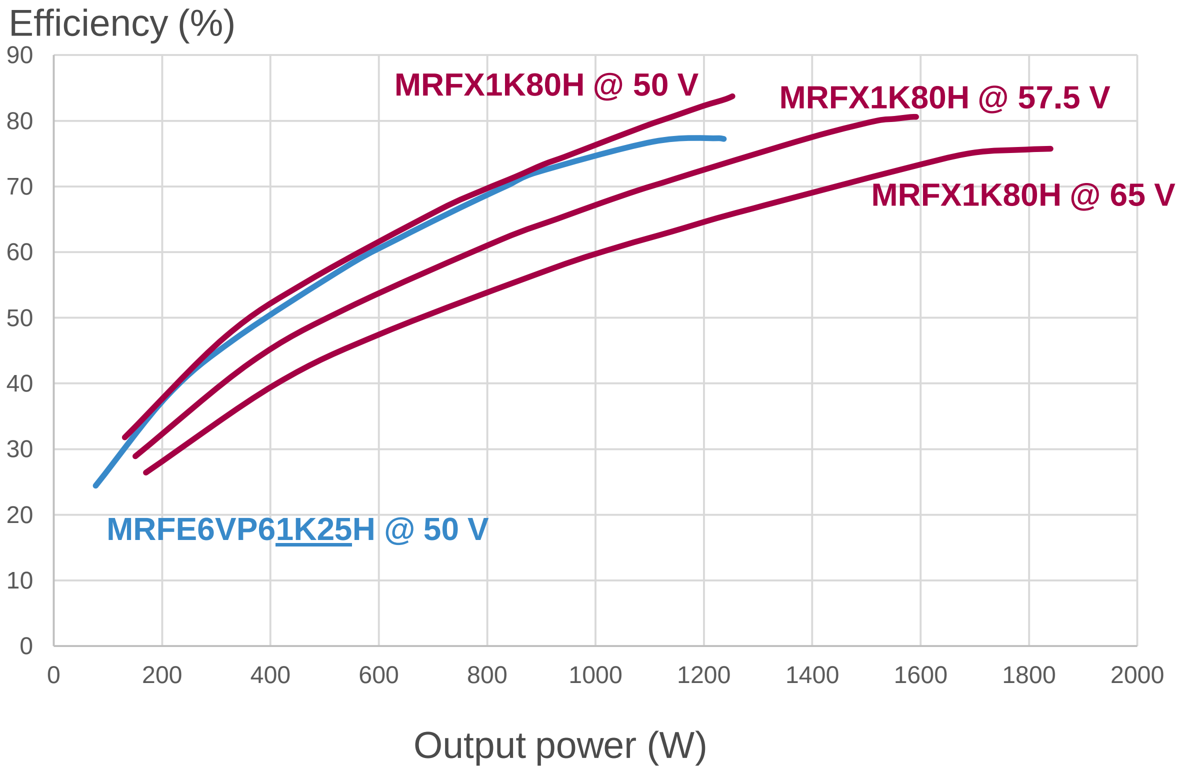
- Faster Time-To-Market
- One platform, multiple products

Easy Upgrade from Existing 50 V Solutions

Data taken on the same 27 MHz reference circuit: no retuning







Pin = 3W, CW	Vdd	Pout	Gain	Efficiency
MRFE6VP61K25H	50 V	1170 W	25.8 dB	77.1%
MRFX1K80H	50 V	1200 W	26.0 dB	82.3%
	57.5 V	1520 W	27.0 dB	80.1%
	65 V	1800 W	27.8 dB	75.6%

Why 65V? Ease of use.

More power – Higher voltage enables higher power density, which helps reduce the number of transistors to combine.

Fewer combining losses, smaller PAs, simpler power supply management.

Faster development time – With higher voltage, the output power can be increased while retaining a reasonable output impedance.

Easier matching to 50 ohms; transistors can be used wideband.

Design reuse – This impedance benefit also ensures pin-compatibility with current 50 V LDMOS transistors for better scalability.

Little to no retuning from existing 50 V power amplifiers.

Manageable current level – Higher voltage reduces the current losses in the system.

Fewer stresses on DC supplies, better system efficiency, less magnetic radiation.

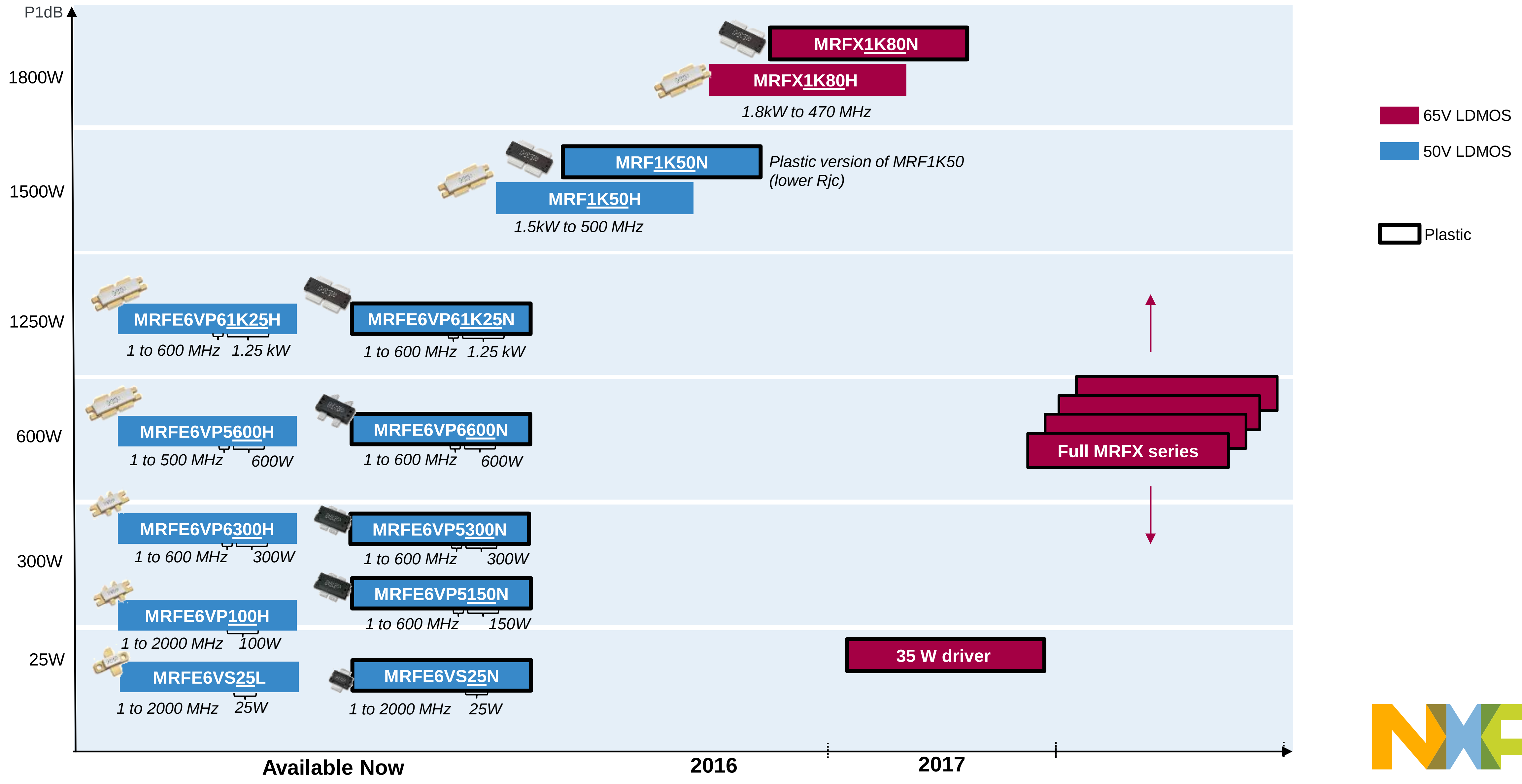
Wide safety margin – The higher breakdown voltage of 182 V improves ruggedness and allows for higher efficiency classes of operation.

Better reliability, higher efficiency.

MRFX SERIES OVERVIEW

NXP RF Power 1-500 MHz Roadmap

All watts are CW.



MRFX1K80 Target Markets

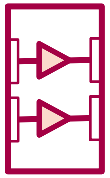
- **Industrial, Scientific, Medical (ISM)**
  - Laser generation
  - Plasma etching
  - Magnetic Resonance Imaging (MRI)
  - Diathermy, skin laser, RF ablation
  - Industrial heating, welding and drying systems
  - Particle accelerators
- **Broadcast**
  - Radio broadcast (FM/DAB)
  - VHF TV broadcast
- **Aerospace**
  - VHF omnidirectional range (VOR)
  - HF and VHF communications
  - Weather radar
- **Mobile Radio**
  - VHF base stations



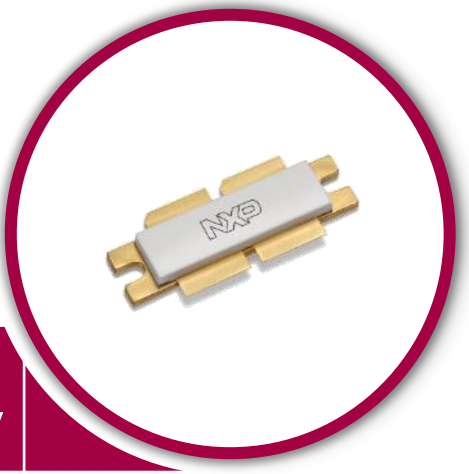

MRFX1K80H

- **1800 W CW**
- **1.8-470 MHz**
- **65 V LDMOS**
- Unmatched input and output
- Push-pull
- NI-1230 air cavity ceramic package
- 0.09°C/W thermal resistance
- 182 V min breakdown voltage $V_{(BR)DSS}$
- Extreme ruggedness: handles 65:1 VSWR
- Warranted availability until 2032 minimum

Comments:



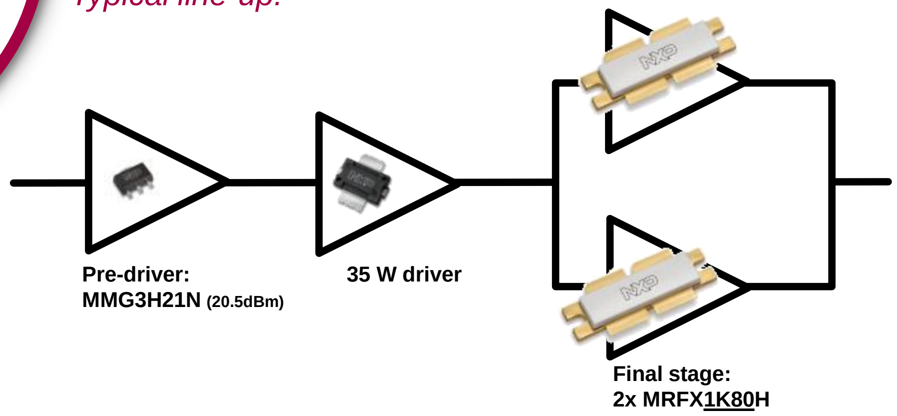
- *Sampling now (PRFX1K80H preliminary transistors available at Richardson RFPD)*
- *Production August 2017*



Typical performance:

Frequency	Signal type	Voltage	Pout	Gain	Drain efficiency	
27	CW	50	1200	26.0	82.3	April
		57.5	1520	27.0	80.1	
		65	1800	27.8	75.6	
87.5-108	CW	50	1140	19.8	83.4	April
		60	1615	21.3	82.6	
144	CW	65	1800	23.5	77.5	July
230	Pulse	65	1800	24.0	74.0	July

Typical line-up:



MRFX1K80N

- **1800 W CW**
- **1.8-470 MHz**
- **65 V LDMOS**
- Unmatched input and output
- Push-pull
- OM-1230 over-molded low-Rjc plastic package (30% lower thermal resistance)
- 182 V min breakdown voltage $V_{(BR)DSS}$
- Extreme ruggedness: handles 65:1 VSWR
- Warranted availability until 2032 minimum

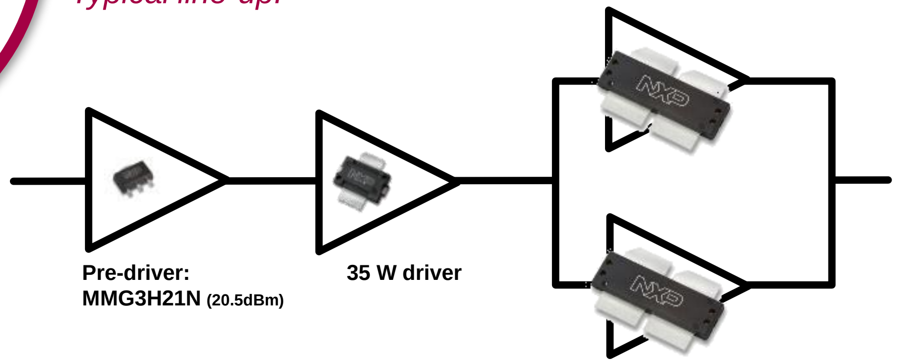
Comments:

- *Sampling Q3 2017*
- *Production Q4 2017*

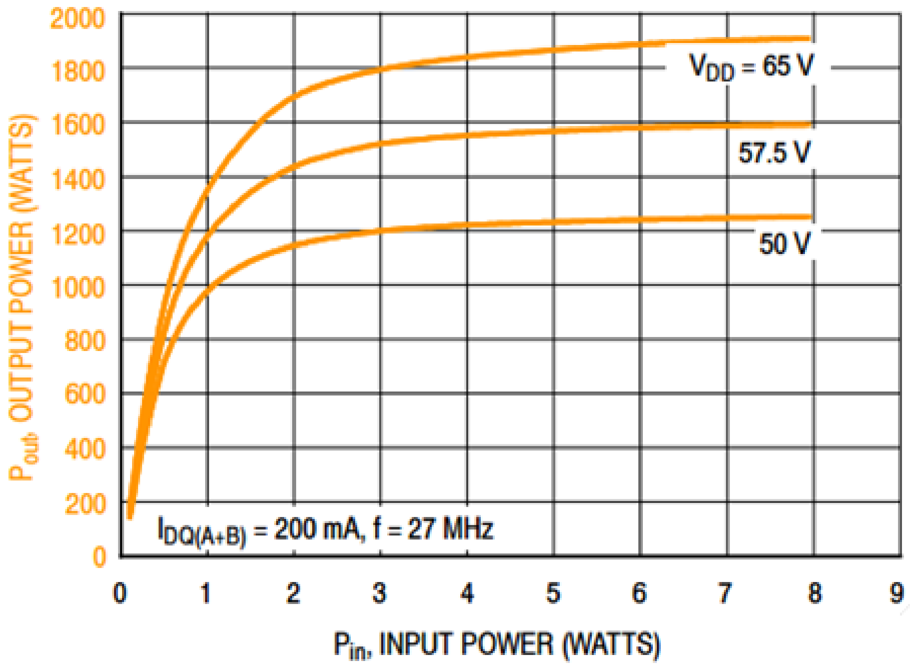
Target performance:

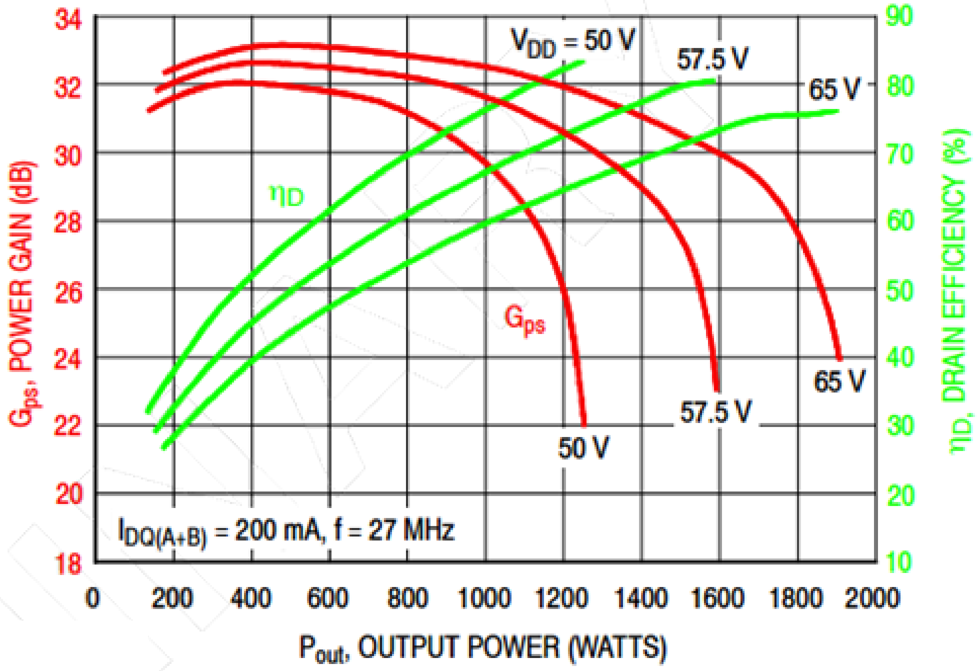
Board Frequency (MHz)	Signal type	Vdd (V)	Power (W)	Gain (dB)	Drain Eff. (%)
230	Pulse	65	1800 peak	24	74%

Typical line-up:



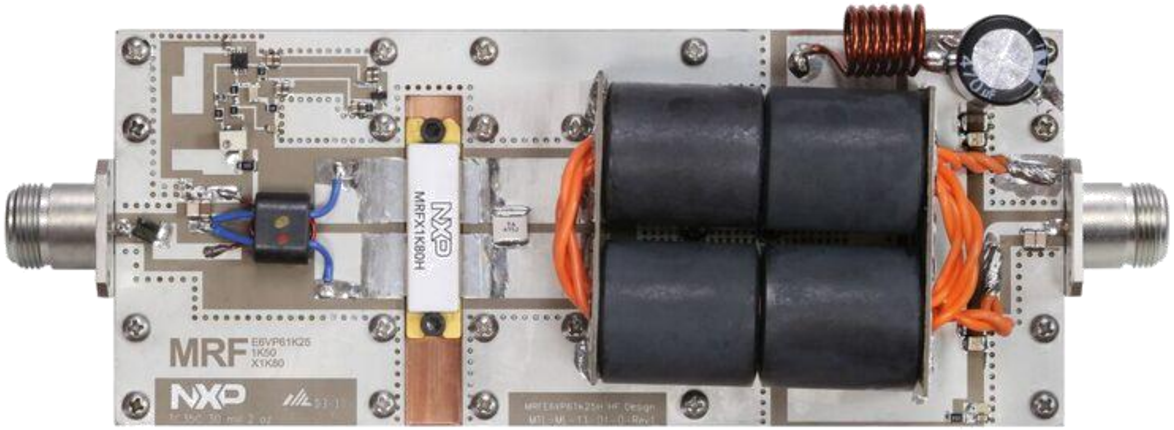
MRFX1K80H Typical performance at 27 MHz





At Pin = 3 W:

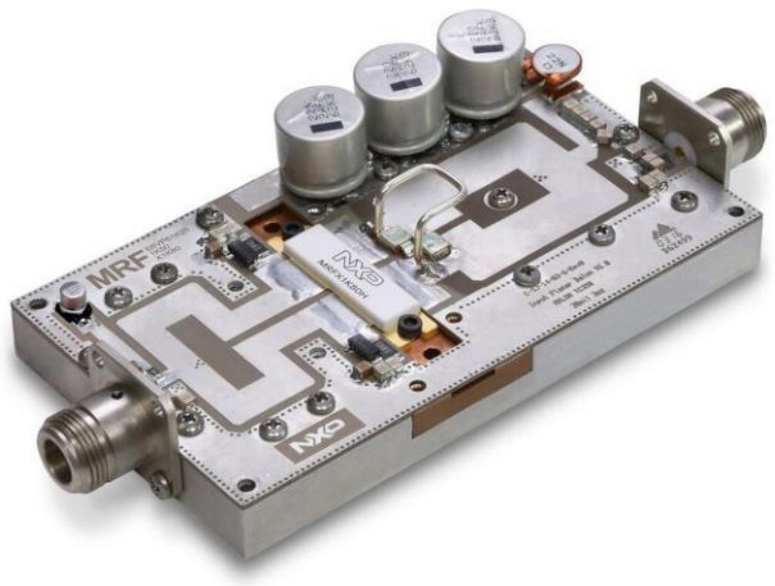
V_{DD} (V)	P_{out} (W)	G_{ps} (dB)	η_D (%)
50	1200	26.0	82.3
57.5	1520	27.0	80.1
65	1800	27.8	75.6

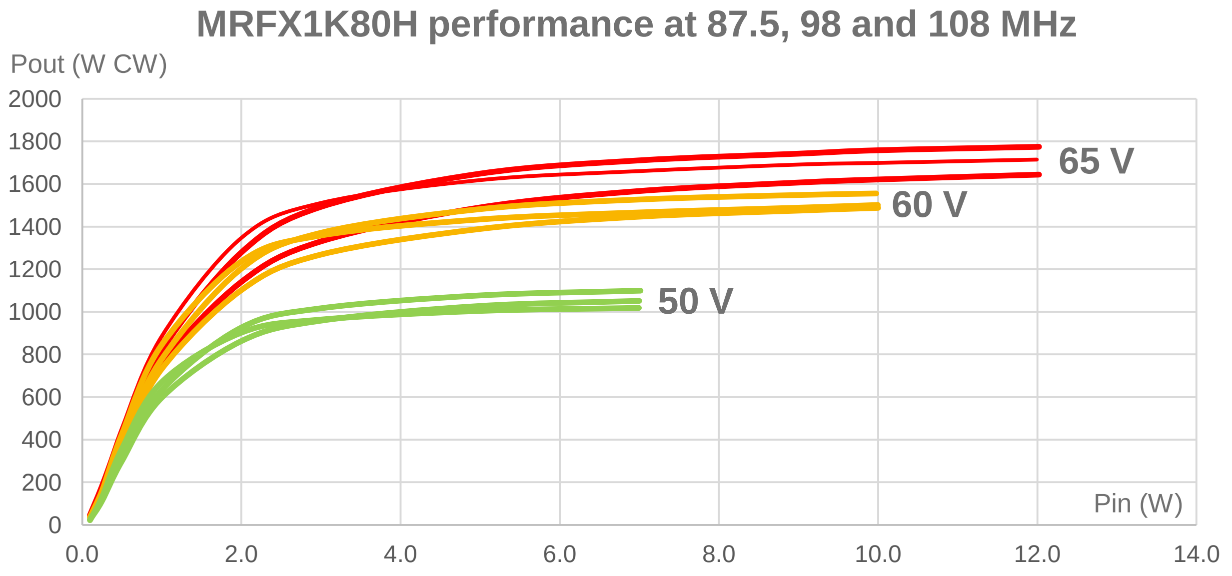


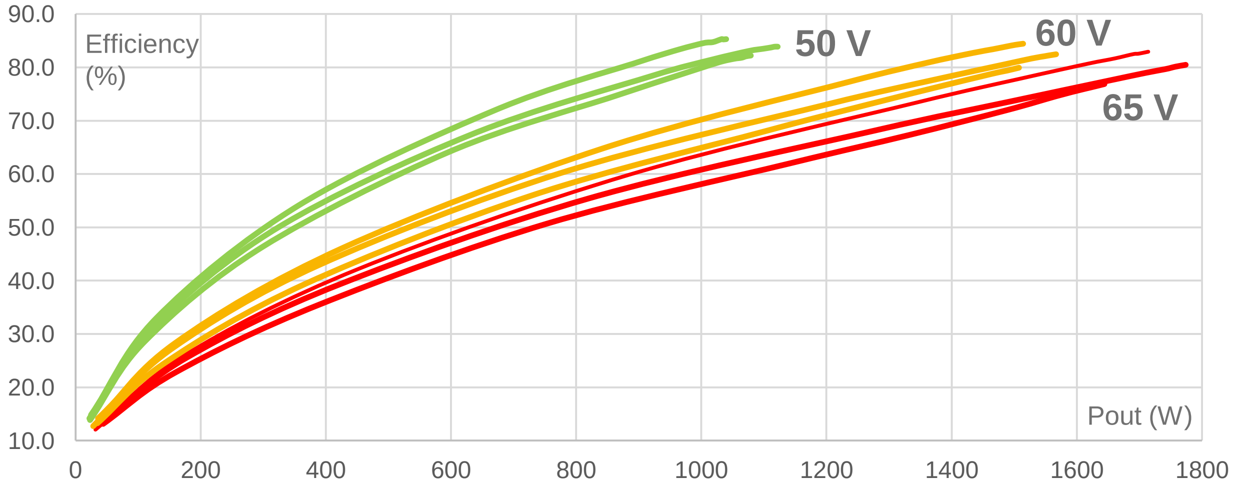
2.88 × 6.91” (73 × 176 mm)

87.5-108 MHz performance details

- These graphics show the FM performance of MRFX1K80H at various drain voltages.
- 60 V is a good trade-off for 87.5-108 MHz wideband performance between thermal management, efficiency and external components reliability, enabling 1500 W minimum over the full band.

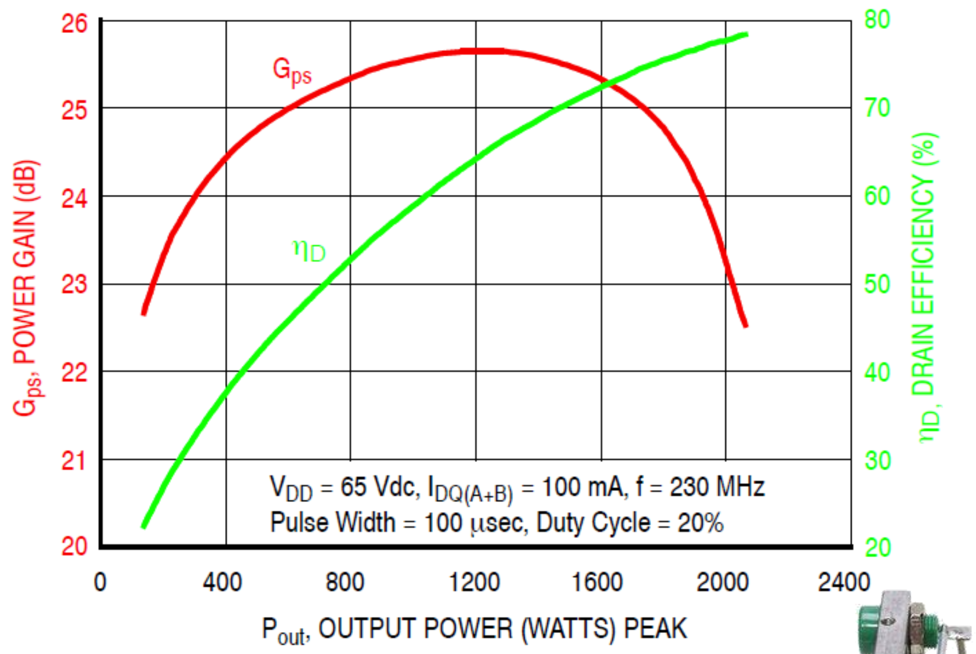




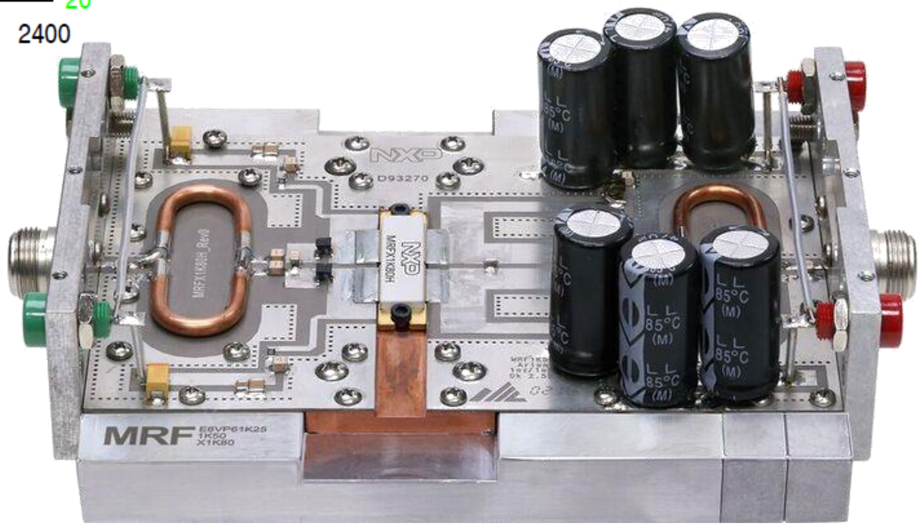


MRFX1K80H Typical performance at 230 MHz

NXP's production test fixture



f (MHz)	P1dB (W)	P3dB (W)
230	1800	2030



6×4" (152 mm × 102 mm)

MRFX1K80H Typical performance at 230 MHz 2/2

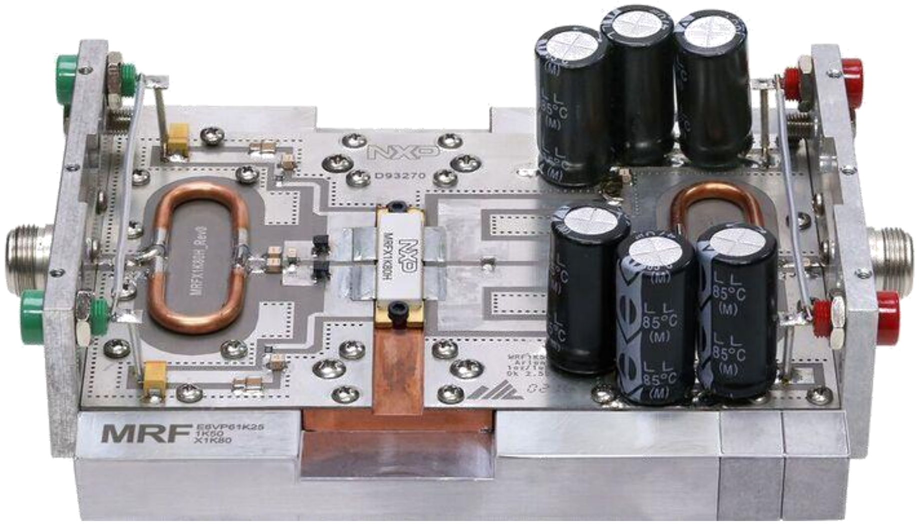
NXP's production test fixture

Functional Tests (In NXP Production Test Fixture, 50 ohm system) V_{DD} = 65 Vdc, $I_{DQ(A+B)}$ = 100 mA, P_{out} = 1800 W Peak (360 W Avg.), f = 230 MHz, 100 μsec Pulse Width, 20% Duty Cycle

Power Gain	G_{ps}	23.0	24.0	—	dB
Drain Efficiency	η_D	69.0	74.0	—	%
Input Return Loss	IRL	—	–15	–9	dB

Datasheet page 2 excerpt

Each transistor is tested in production at 1800 W, at 230 MHz with 100us and 20% duty cycle signal



6×4" (152 mm × 102 mm)

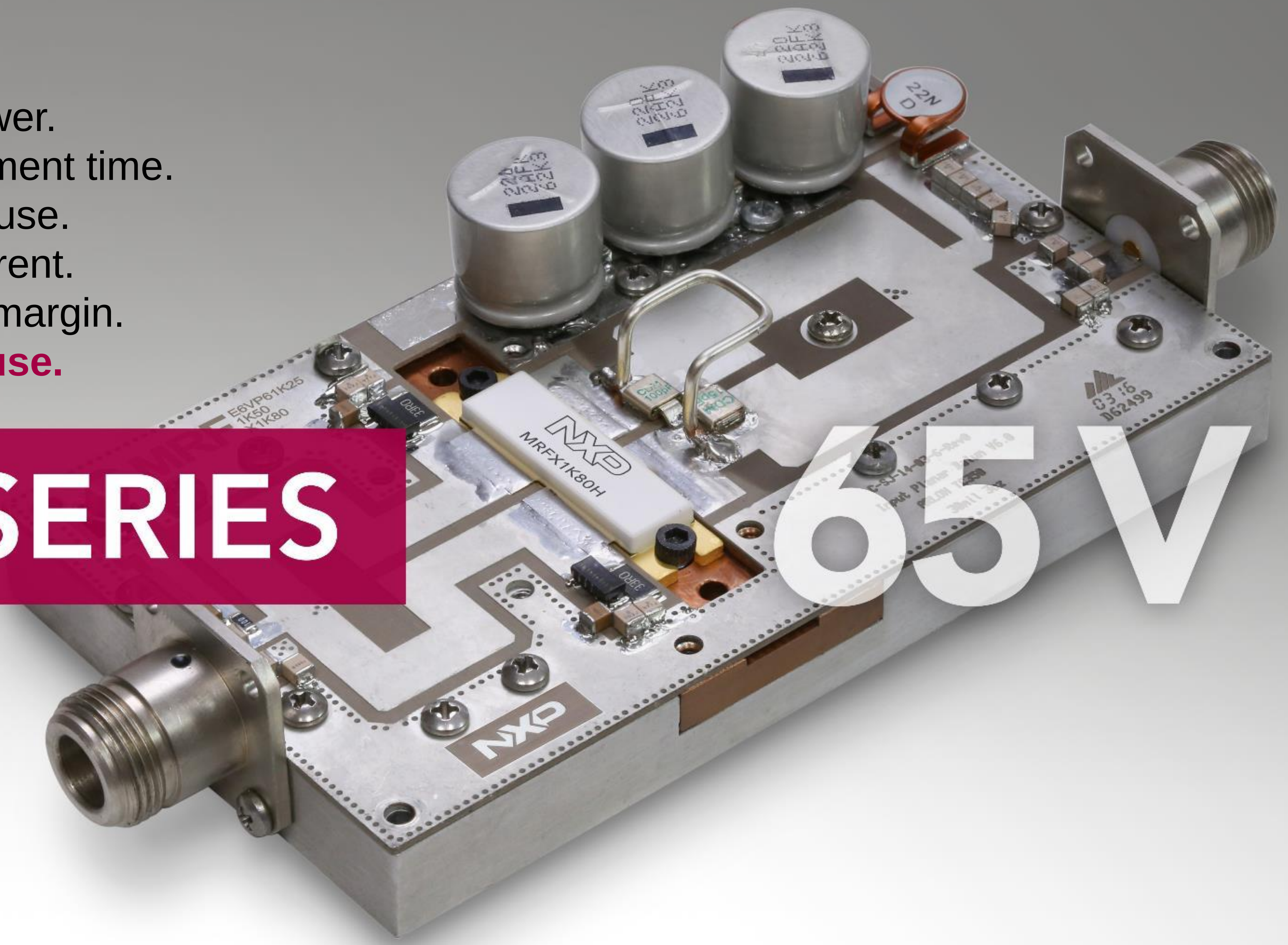
For more information about MRFX1K80H

www.nxp.com/65V

www.nxp.com/MRFX1K80H

More power.
Faster development time.
Design reuse.
Lower current.
Wide safety margin.
Easy to use.

MRFX SERIES



65 V

NXP

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FOR A SMARTER WORLD