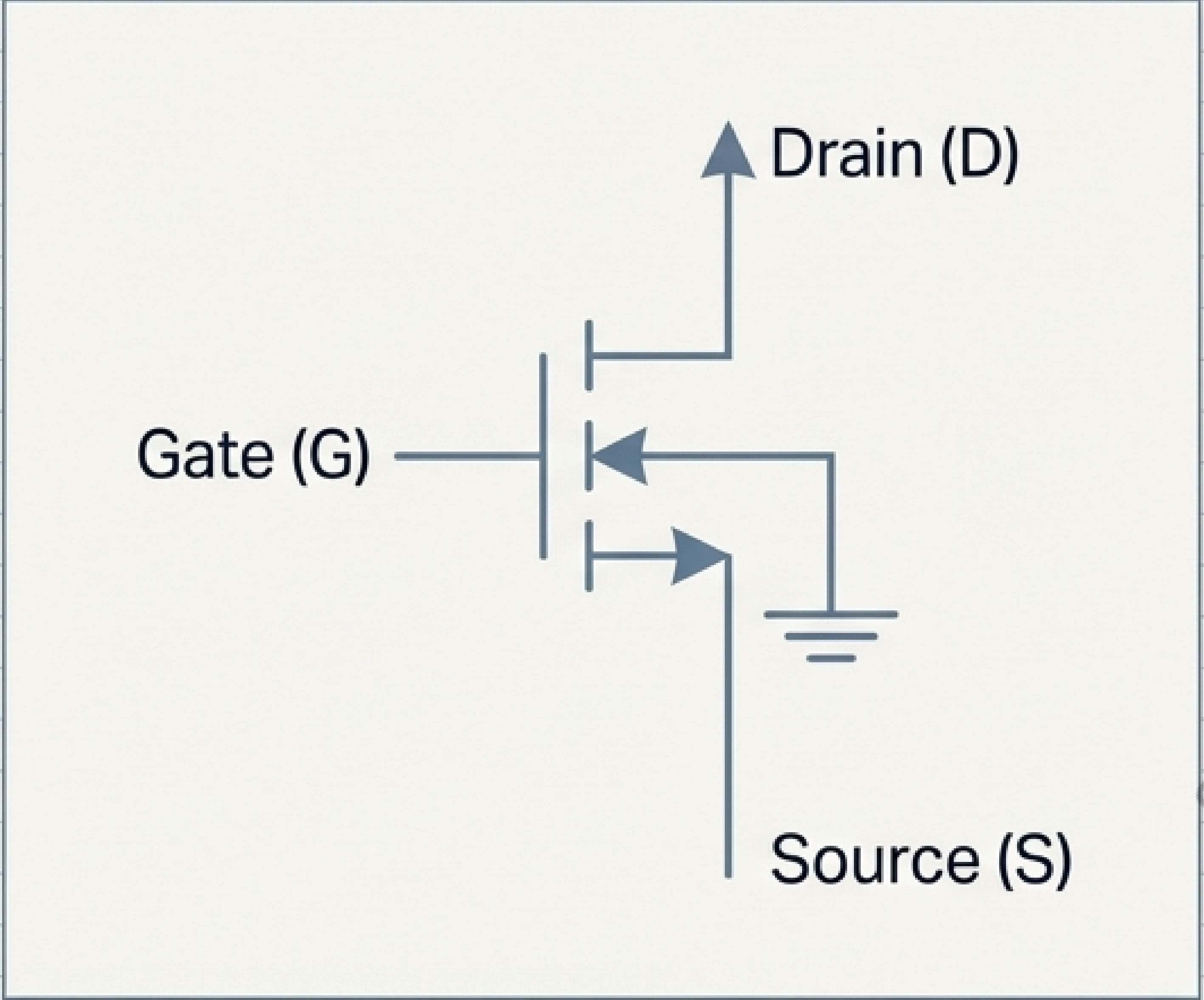
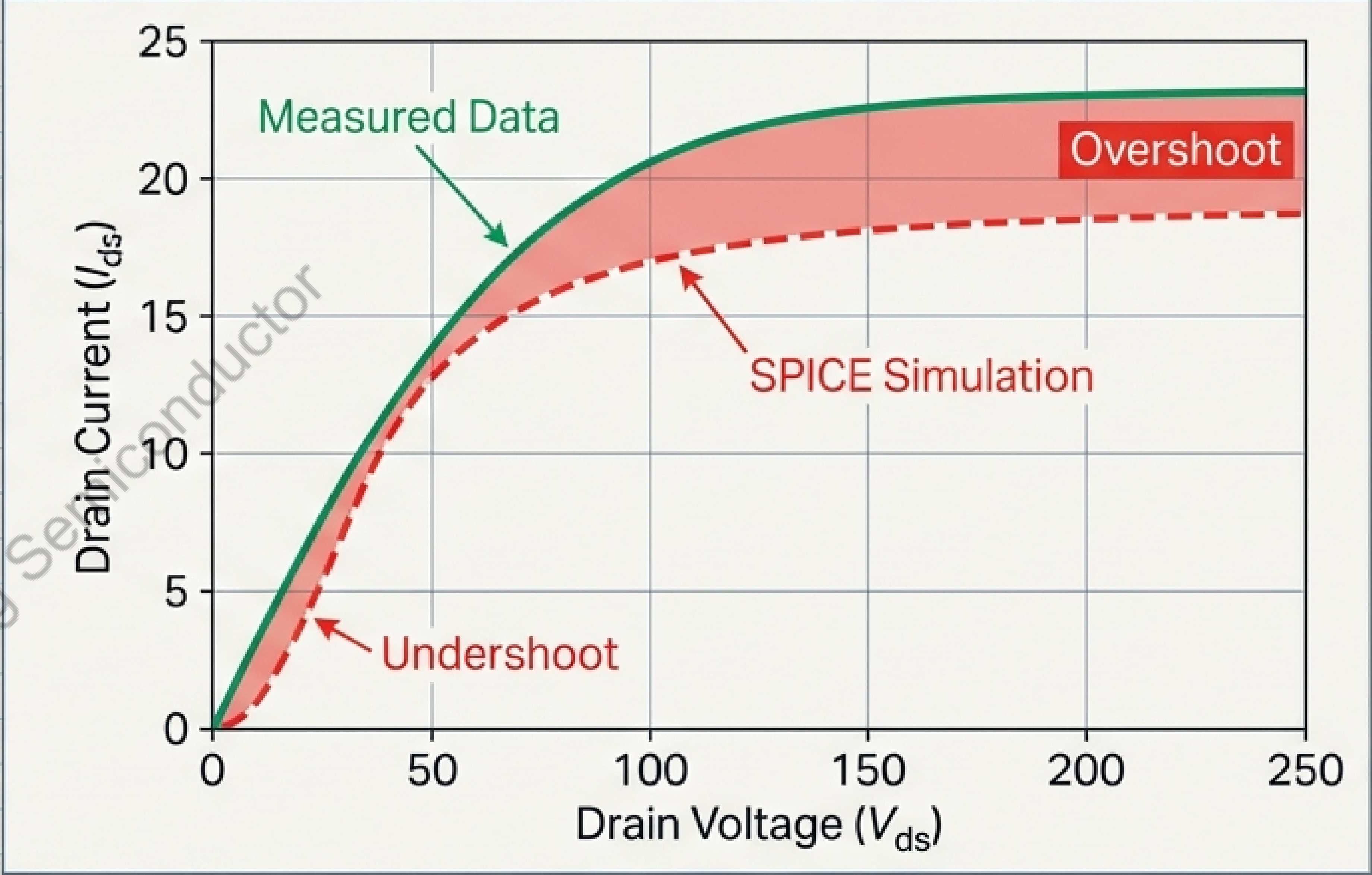
A Parameter-Tuning Strategy for GaN HEMT Model Correction

Targeting Dynamic On-Resistance and Saturation Matching to Resolve Waveform Artifacts.





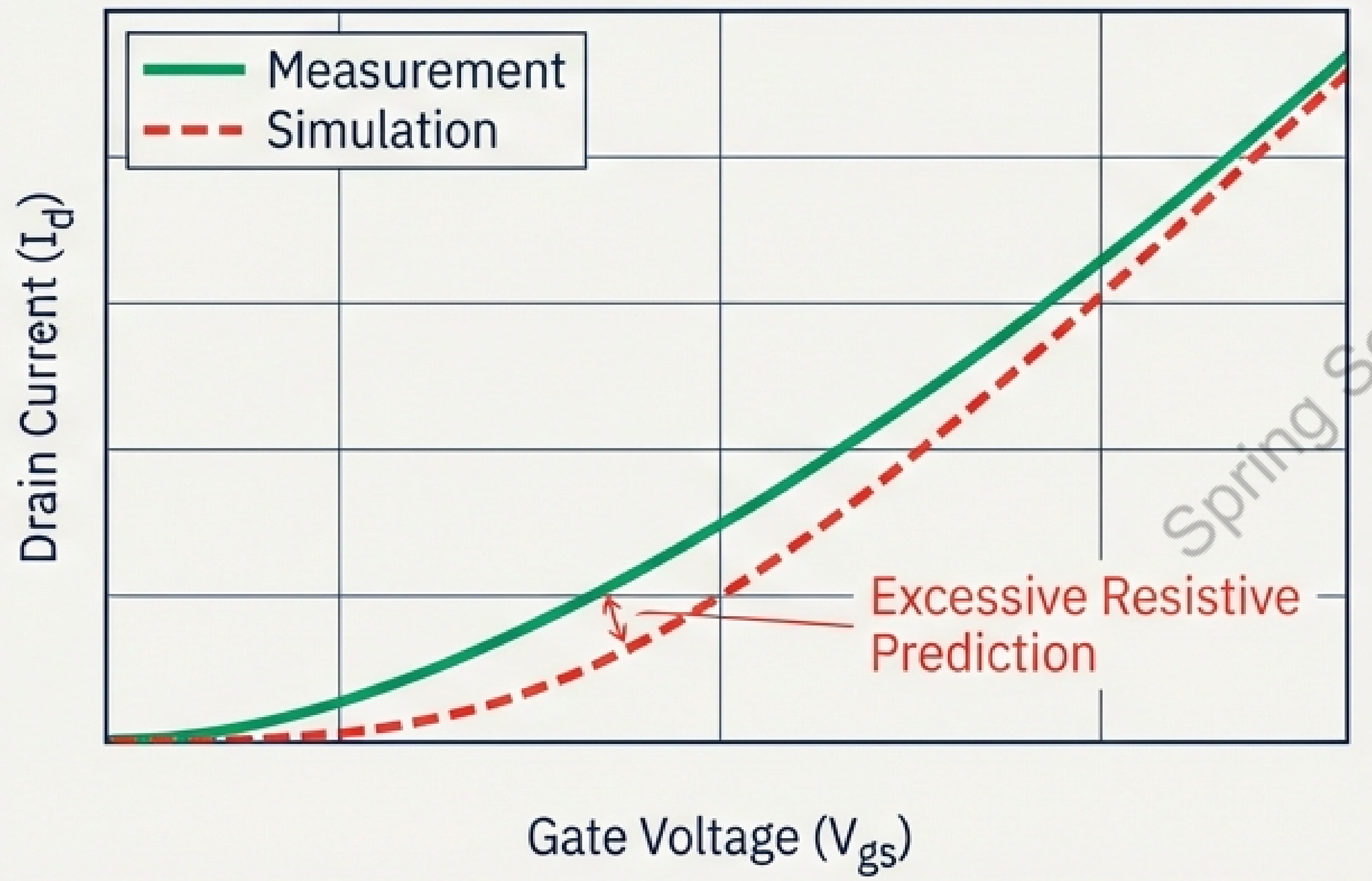
EXECUTIVE SUMMARY

- **Objective:** Address discrepancies between SPICE models and lab measurements for Gallium Nitride HEMTs.
- **Method:** A systematic protocol to diagnose waveform artifacts and calibrate parameters (I_{para}, R_{ds}, $k3$-$k5$).
- **Core Philosophy:** Moving beyond random tweaking to address underlying physics (Dynamic $R_{DS,on}$).

Waveform Artifacts are Physical Clues, Not Random Noise

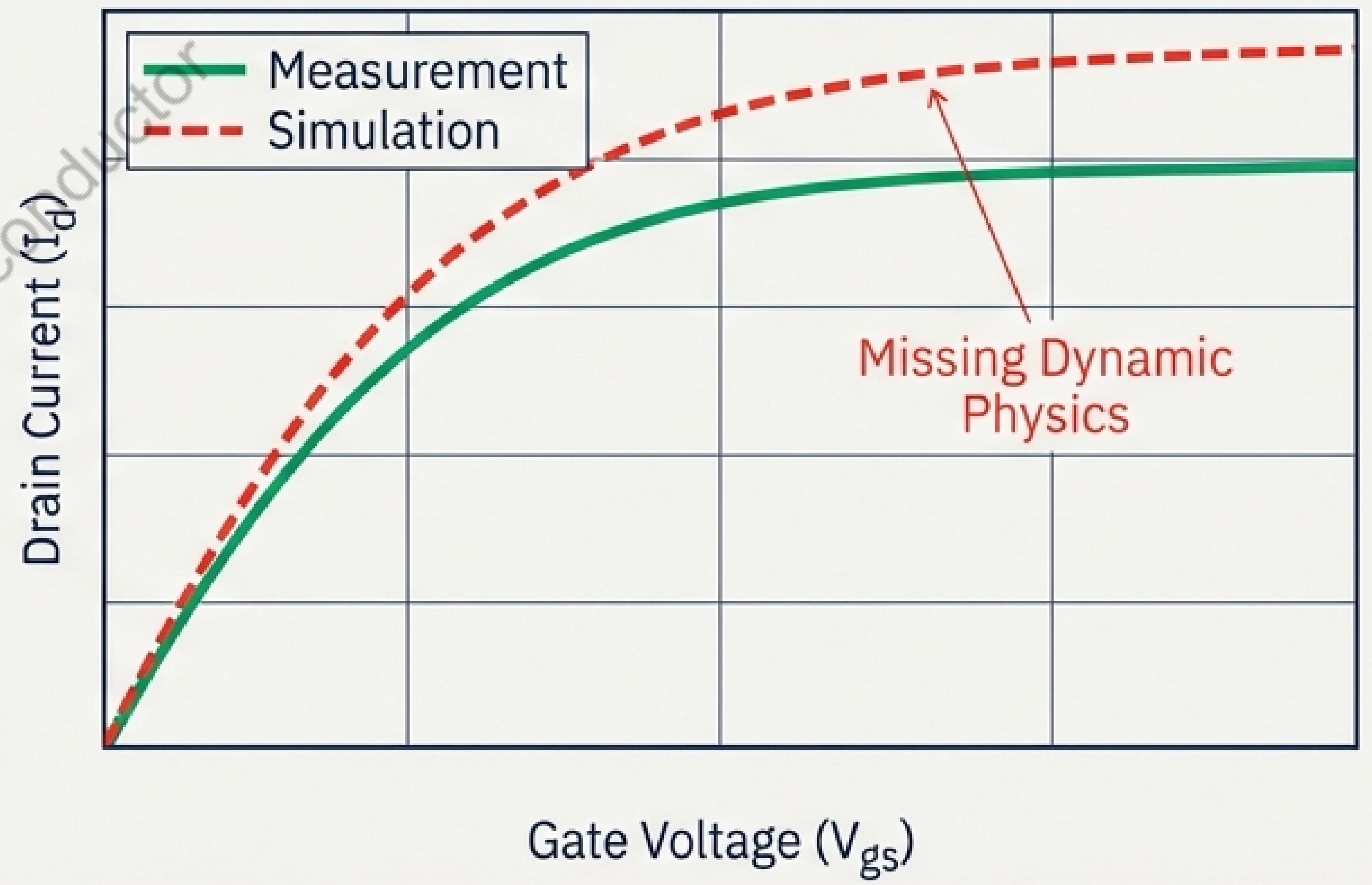
Discrepancies reveal specific deficiencies in the model's formulation.

The Symptom: Low-Vgs Undershoot



Diagnosis: Model predicts overly resistive channel. Signals issues with Series Resistance or low-field mobility.

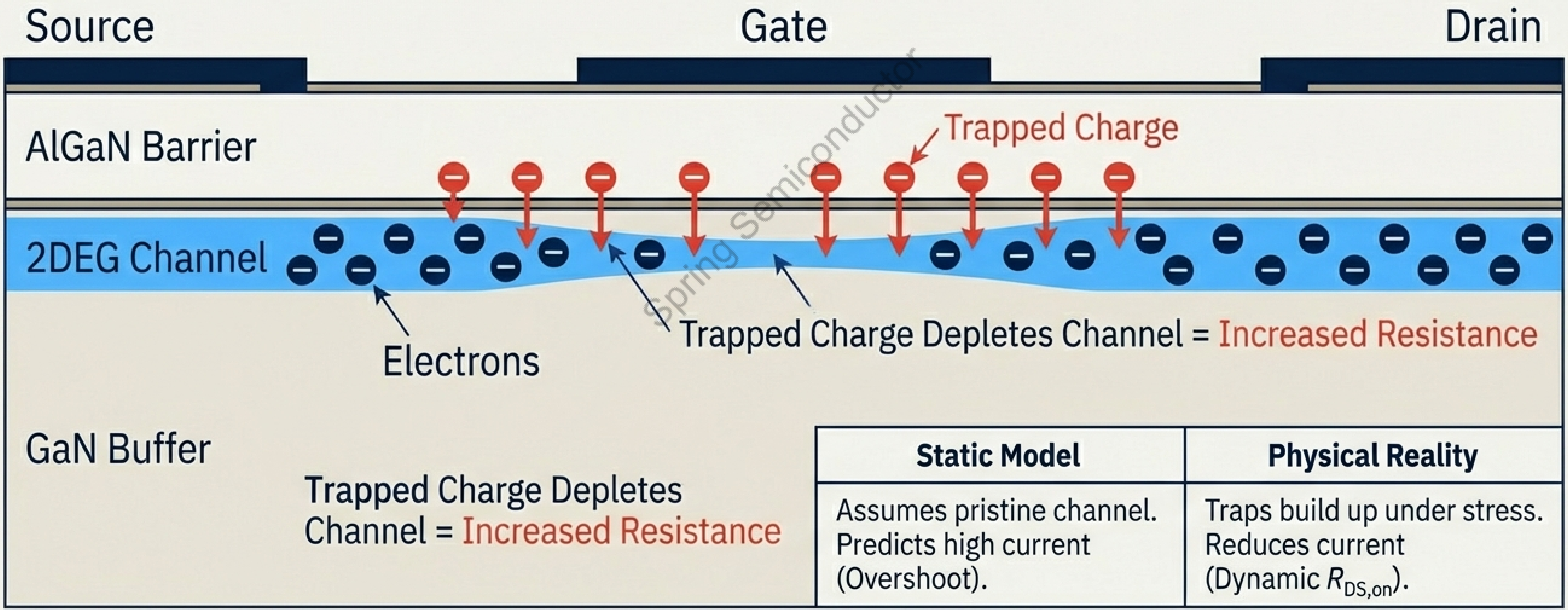
The Symptom: High-Vgs Overshoot



Diagnosis: Model ignores current-limiting phenomena like electron trapping and velocity saturation.

The Root Cause: Dynamic On-Resistance ($R_{DS,on}$)

The overshoot implies the model fails to represent the progressive degradation of channel conductivity due to carrier trapping.

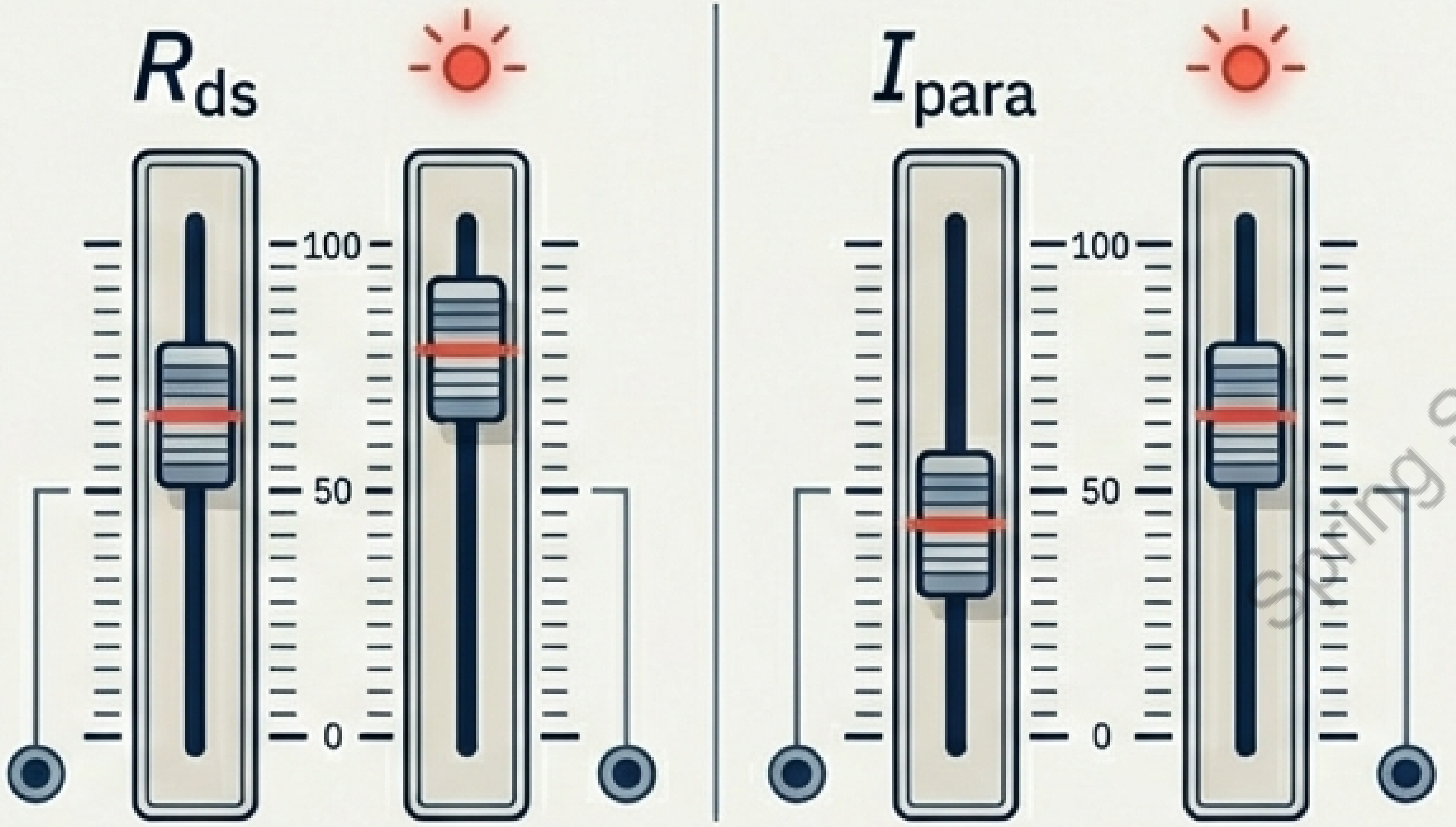


Static Model	Physical Reality
Assumes pristine channel. Predicts high current (Overshoot).	Traps build up under stress. Reduces current (Dynamic $R_{DS,on}$).

The Calibration Toolkit

Separating Global Modulators from Sculpting Tools

Global Modulators (Amplitude & Baseline)



Source/Drain Resistance

Sets baseline impedance and linear slope.

Current Scaling

Master gain control. Multiplies entire curve.

Sculpting Tools (Saturation Shape)

Quadratic Term

Dominant parabolic shape.

Velocity Saturation

Knee transition refinement.

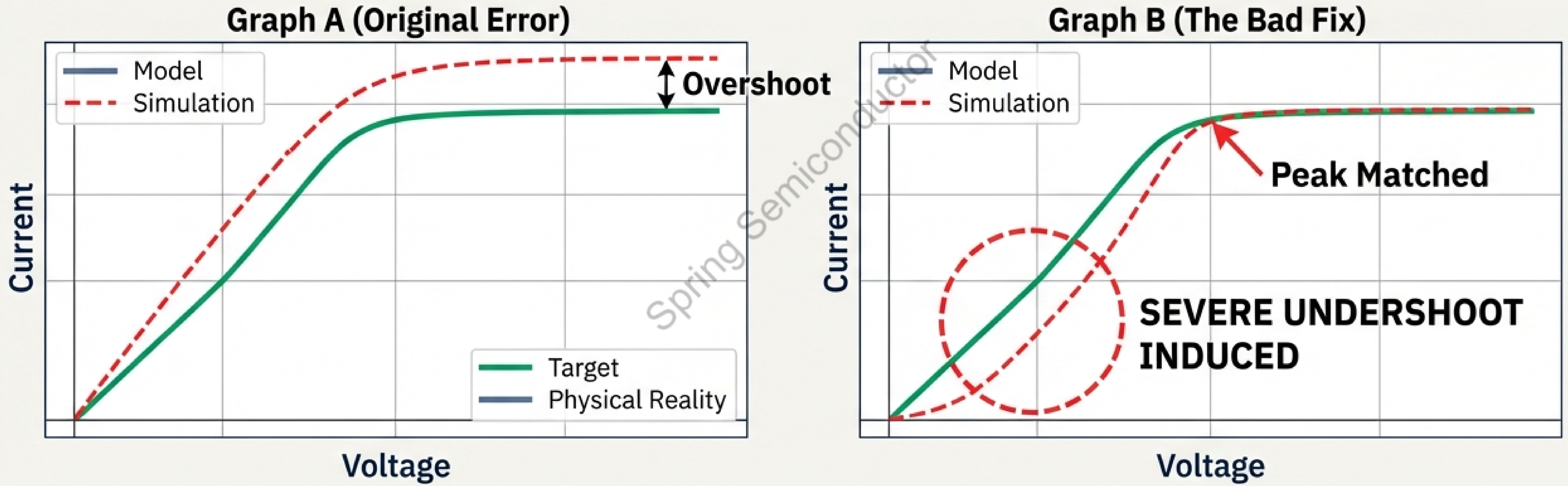
DIBL Correction

Final slope adjust.

The Calibration Trap: Misusing Current Scaling (I_{para})

WARNING: Relying solely on I_{para} masks the root cause.

Before and After

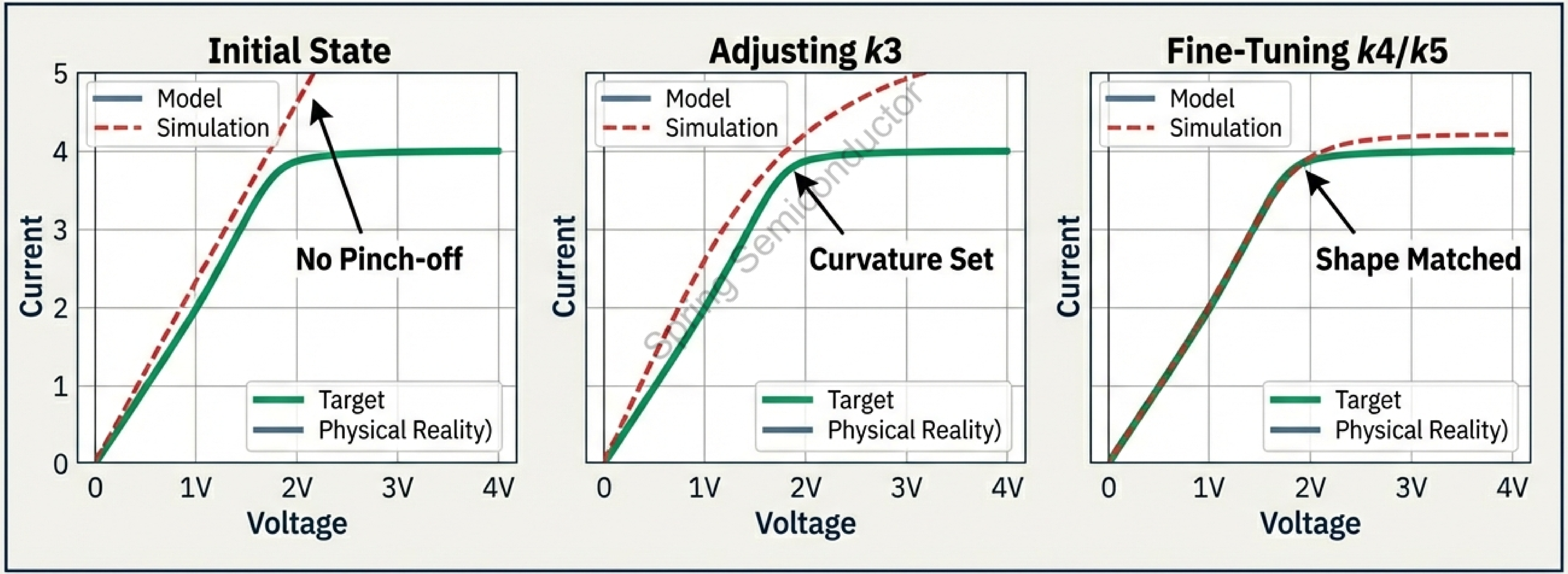


Why it fails: I_{para} shifts the entire curve. Matching the peak creates a massive error in the linear region.

Rule: Only use I_{para} AFTER the shape (knee) is corrected.

Step 1: Sculpt the Saturation Knee (*k*3, *k*4, *k*5)

Force the simulated knee to align with the measured knee physics.

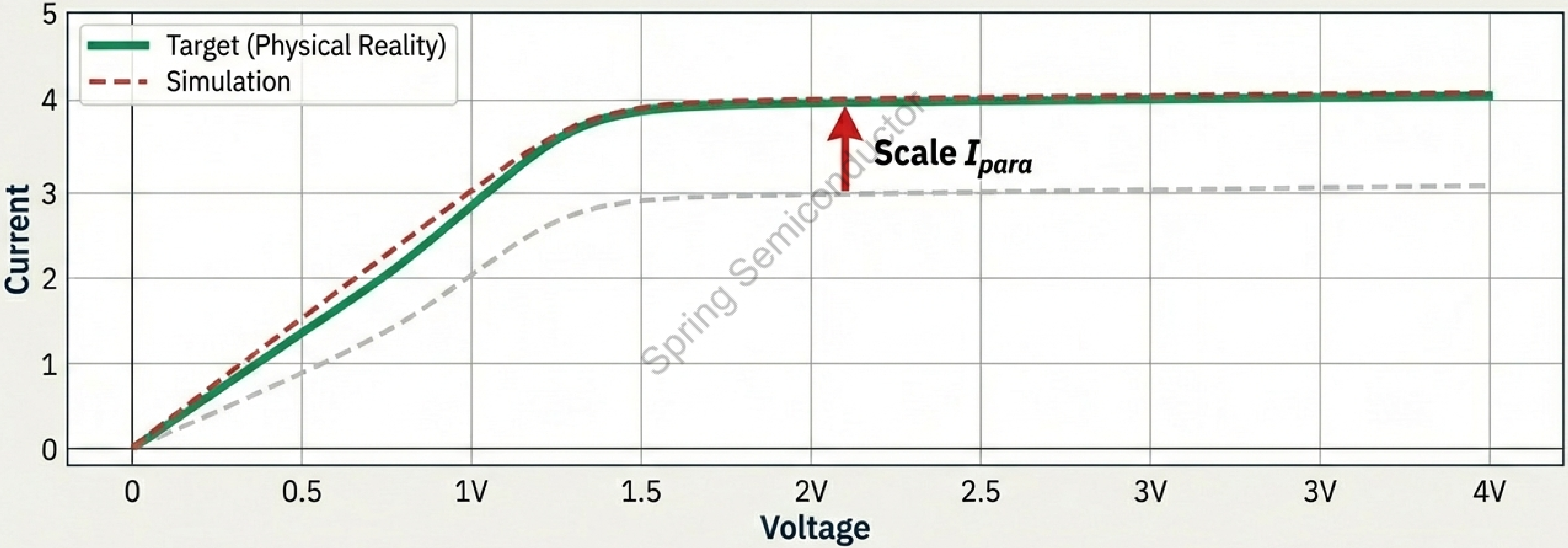


k3: Sets fundamental quadratic roll-off.

k4/k5: Refines inflection point for velocity saturation.

Step 2: Scale the Global Amplitude (I_{para})

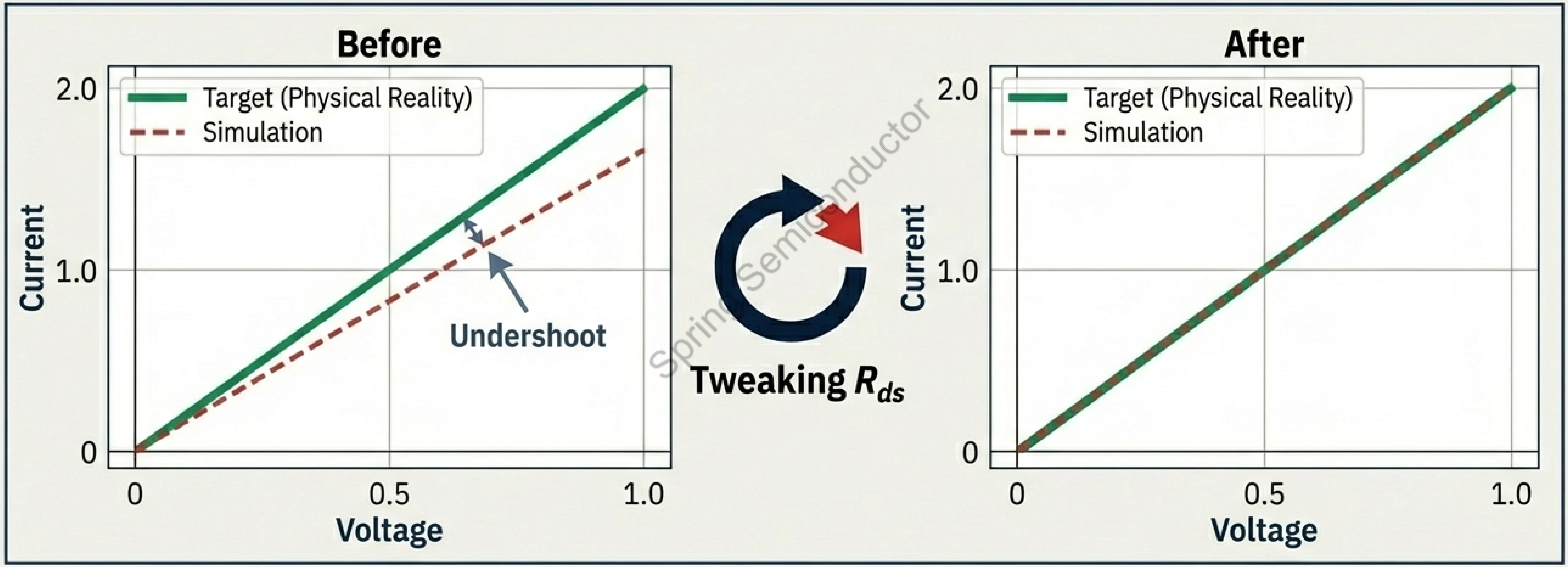
Once the shape is rectified, use the master gain to align peak magnitude.



Because the knee shape was fixed in Step 1, scaling now aligns the saturation region without degrading the linear region.

Step 3: Align the Linear Region (R_{ds})

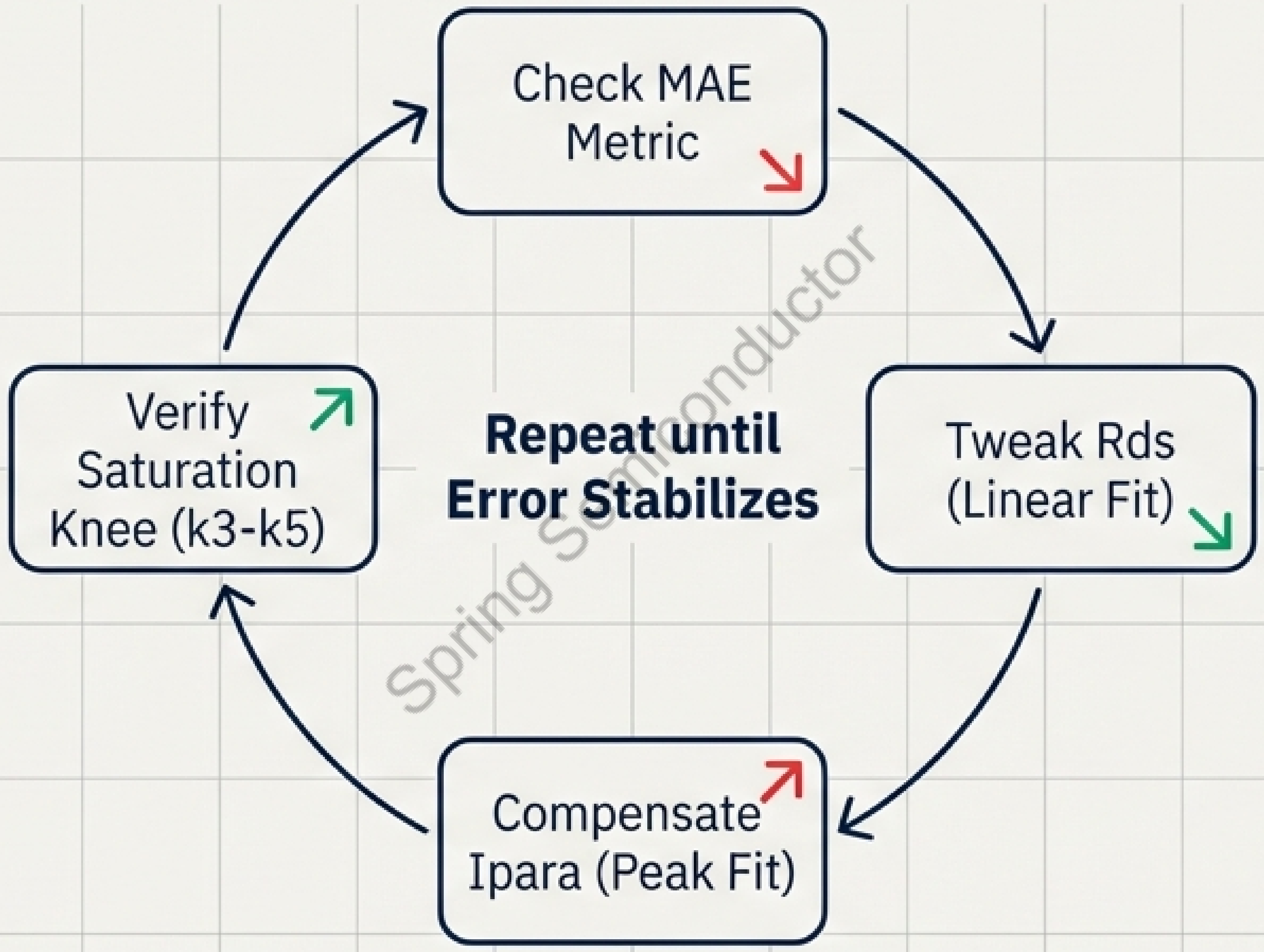
Fine-tune baseline resistance to resolve low-voltage undershoot.



Adjusting **Access Resistance** (***R_{ds}***) pivots the linear slope to match the voltage drop across the device terminals.

Step 4: Iterative Refinement

Converging on Minimum Mean Absolute Error (MAE).



MAE: Average magnitude of difference between predicted and actual values across all points.

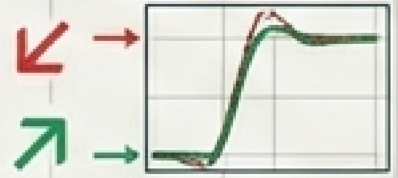
Summary: A Structured Path to Model Fidelity

Key Takeaways

- The "Overshoot" is a shape error, not an amplitude error.
- It is caused by missing Dynamic On-Resistance physics (Trapping).
- Static SPICE models can approximate this behavior if parameters are tuned in the correct order.

The Protocol Checklist

- [ ] **DIAGNOSIS:** Identify Overshoot & Undershoot.



- [ ] **SHAPE:** Tune **$k3, k4, k5$** to match Knee. ✓
- [ ] **SCALE:** Tune I_{para} to match Peak. ✓
- [ ] **BASELINE:** Tune R_{ds} to match Slope. ✓
- [ ] **REFINE:** Iterate to minimize **MAE.**