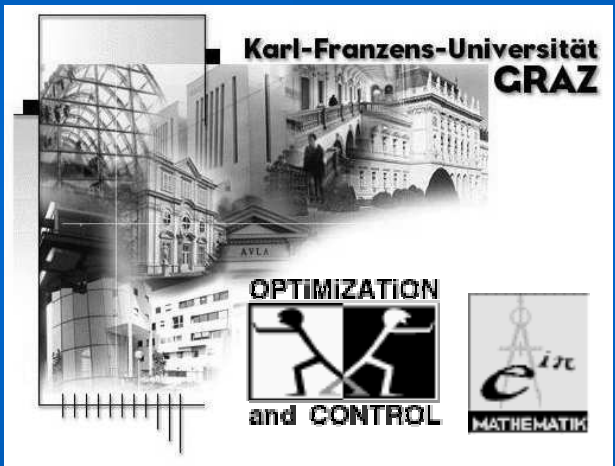
A Muscle-Reflex Model – Steady State Aspects



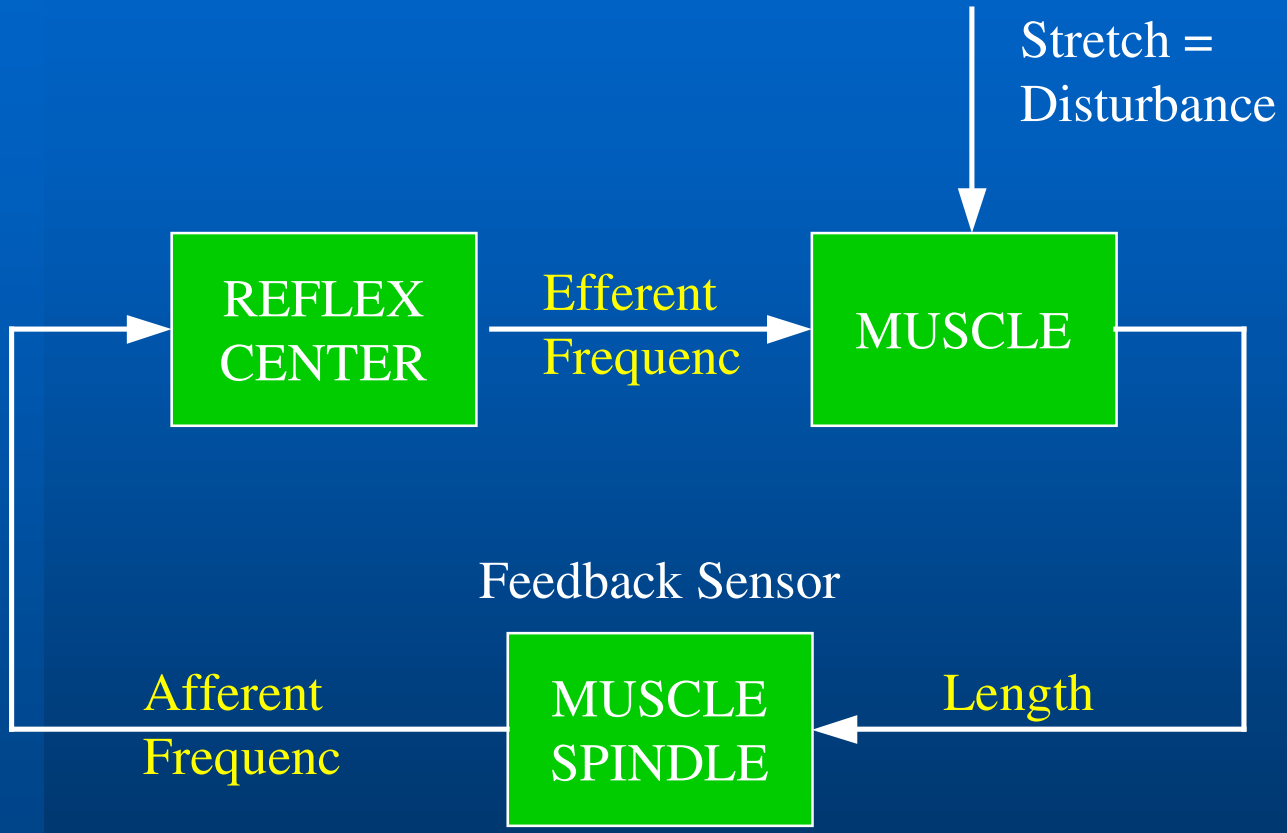
Martin Fink

Special research center for Optimization and Control

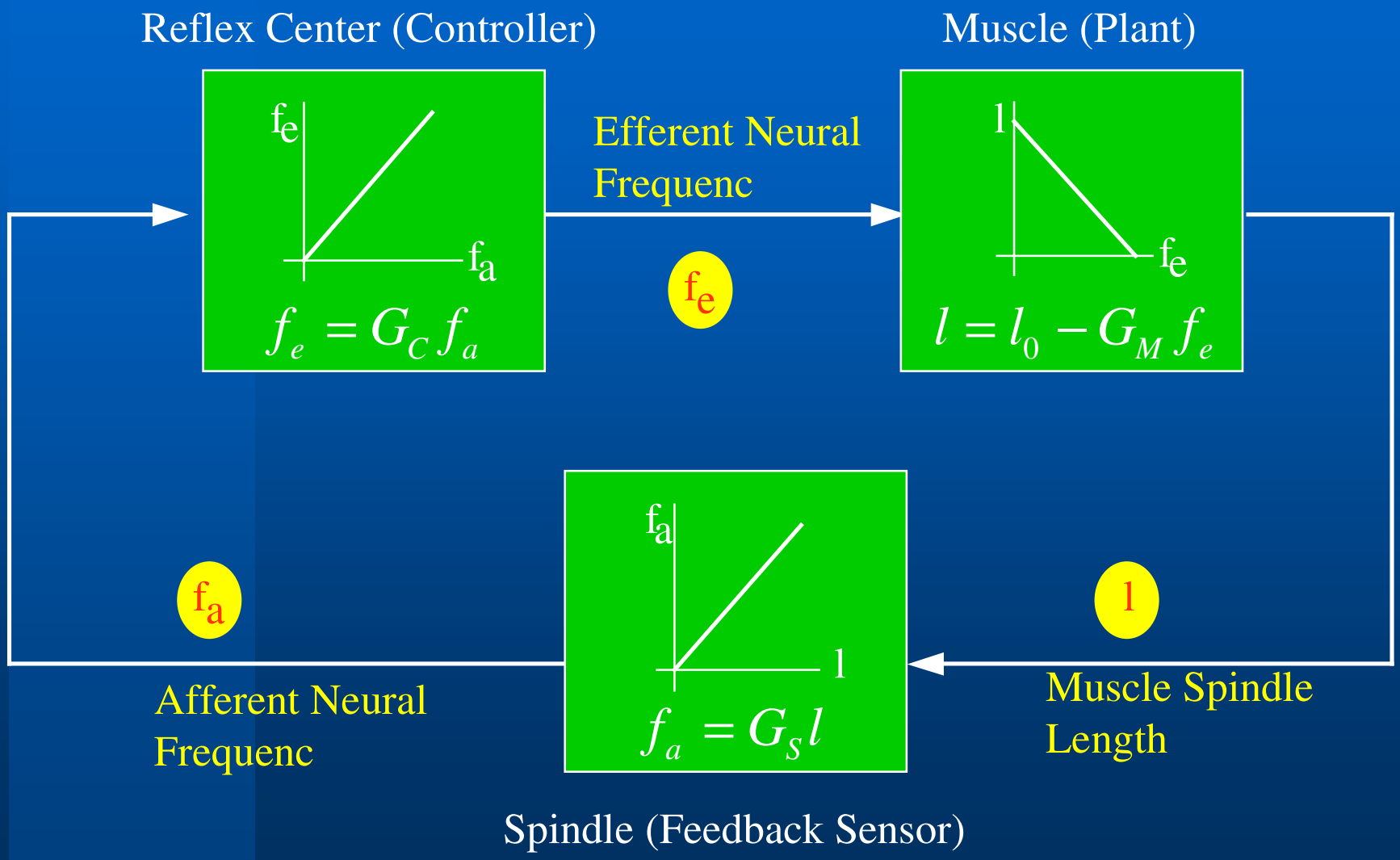
Outline

- Overview
- Linear model
- Steady state operating point
- Iterative calculation
- Intersection method
- Nonlinear model
- Simulink and algebraic loops

Muscle Reflex Model



Linear Model

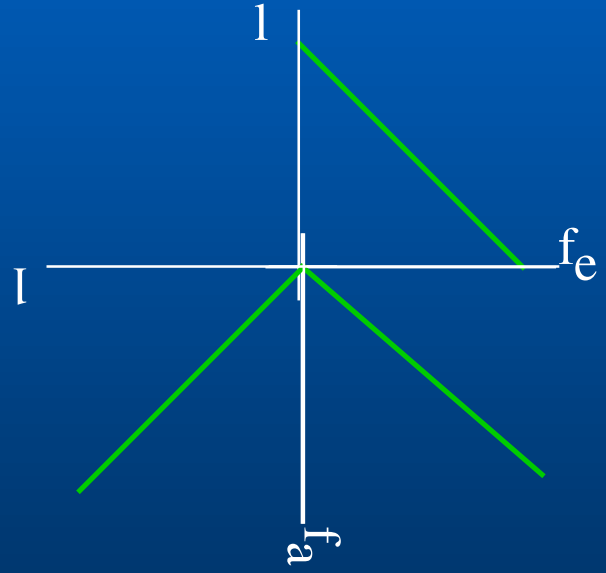


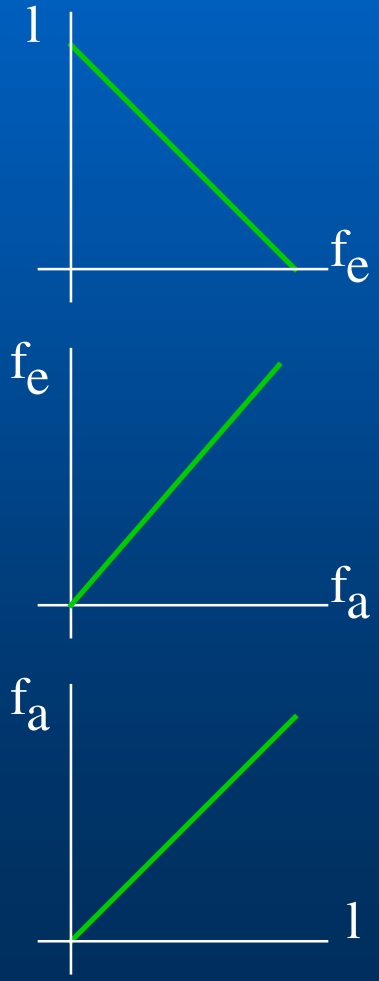
Steady State - Operating Point

- A **steady state** is an operating point for the system, at which the derivative is zero and hence the system does not change.
- In physiological systems – no explicit **set-point**. The steady state is here called **operating point**.
- The operating point depends on the parameters which describe the system and on disturbances.

Steady State – Iterative Calculation

- If you know all separate input/output steady state relations, you can derive the overall steady state.



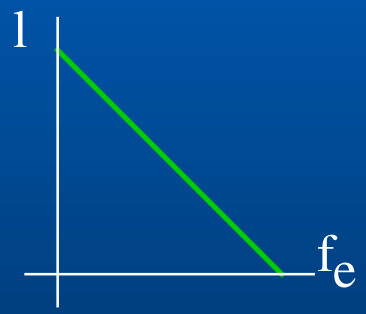


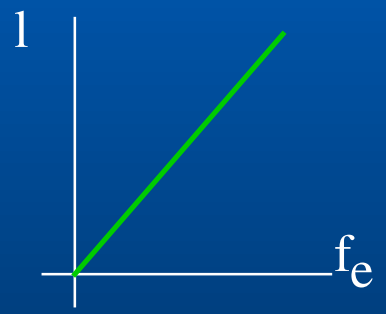
Steady State Calc. – Intersection Method

$$l = l_0 - G_M f_e \qquad f_e = G_C f_a \qquad f_a = G_S l$$

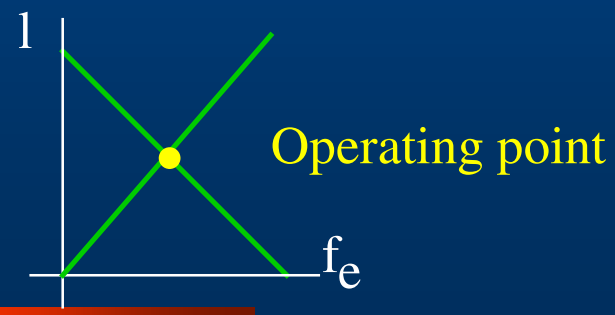
- **Reduce the system equations to two equations...**

$$l = l_0 - G_M f_e \qquad l = \frac{1}{G_C G_S} f_e$$



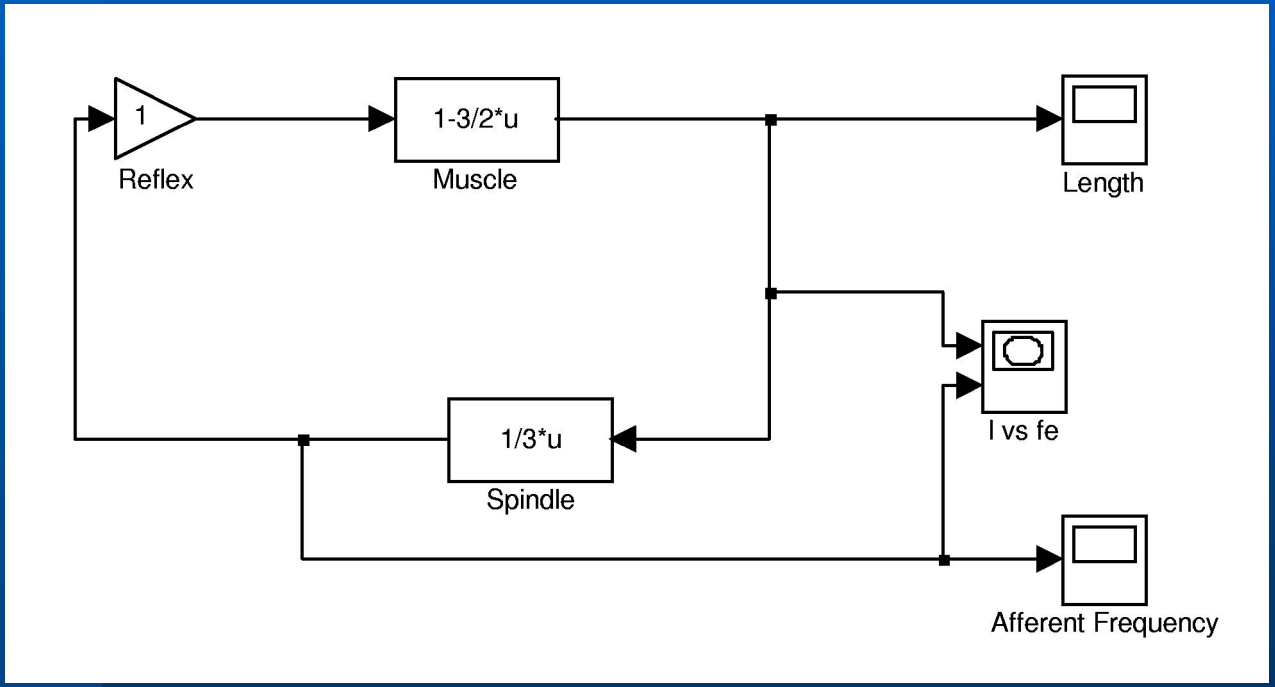


- **... and intersect**

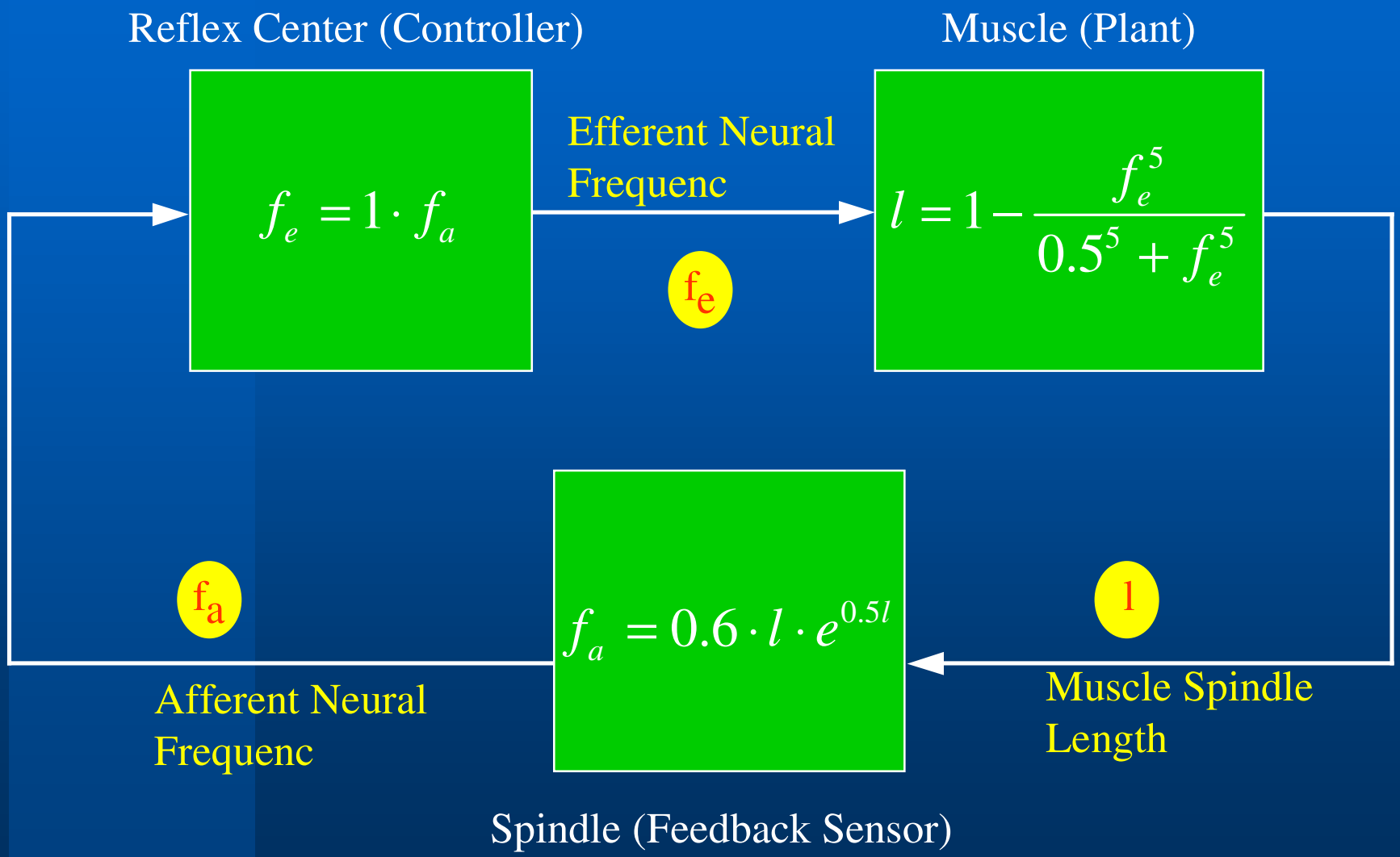


Steady State Linear Model – Simulink

- 3 system blocks
- 3 output blocks

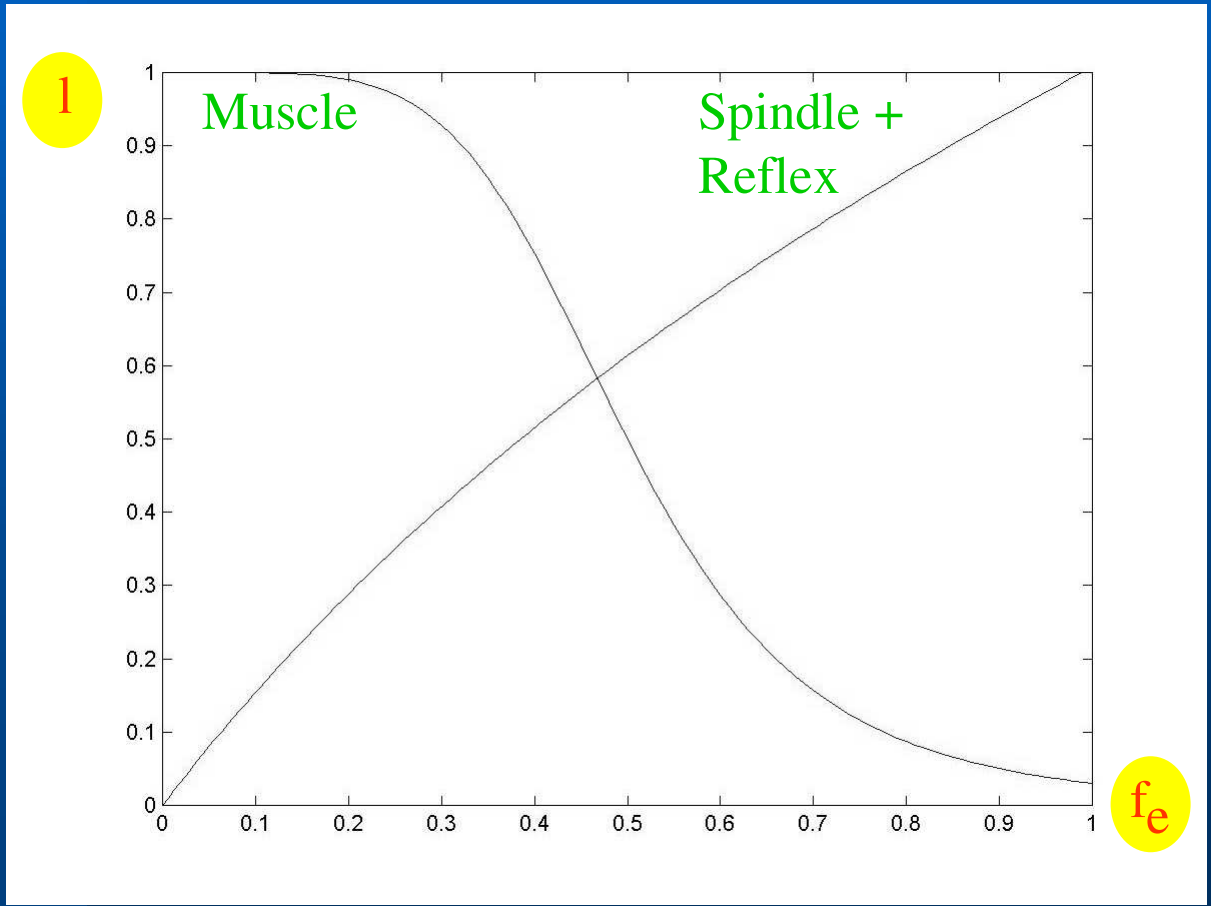


Nonlinear Model



Nonlinear Model – Steady State

- Iterative Calculation does not converge
- Intersection method



Simulink and Algebraic Loops

- **An algebraic loop occurs when**
  - input port with direct feedthrough is driven by the output of the same block
  - or by a feedback path through other blocks with direct feedthrough.
- **Simulink calls a loop solving routine using Newton method at eac time step.**
- **Thus models with algebraic loops run slower than models without them.**