



TE055

Estabilidade: Margens de Ganho e de
Fase

Prof^a Juliana L. M. Iamamura

Estabilidade

Para que um sistema seja estável, devem ser atendidas as condições de módulo e de ângulo:

$$|KG(s)| = 1$$

$$\angle G(s) = 1$$

Essas condições podem ser verificadas nos diagramas de Bode da função.

Estabilidade: exemplo

Seja o sistema a realimentação unitária com a

FTMA $G(s) = \frac{K}{s(s+2)^2}$.

Verifique para que valores de K o sistema é estável.

Trace os diagramas de Bode para $K = 4$, $K = 16$ e $K = 50$.

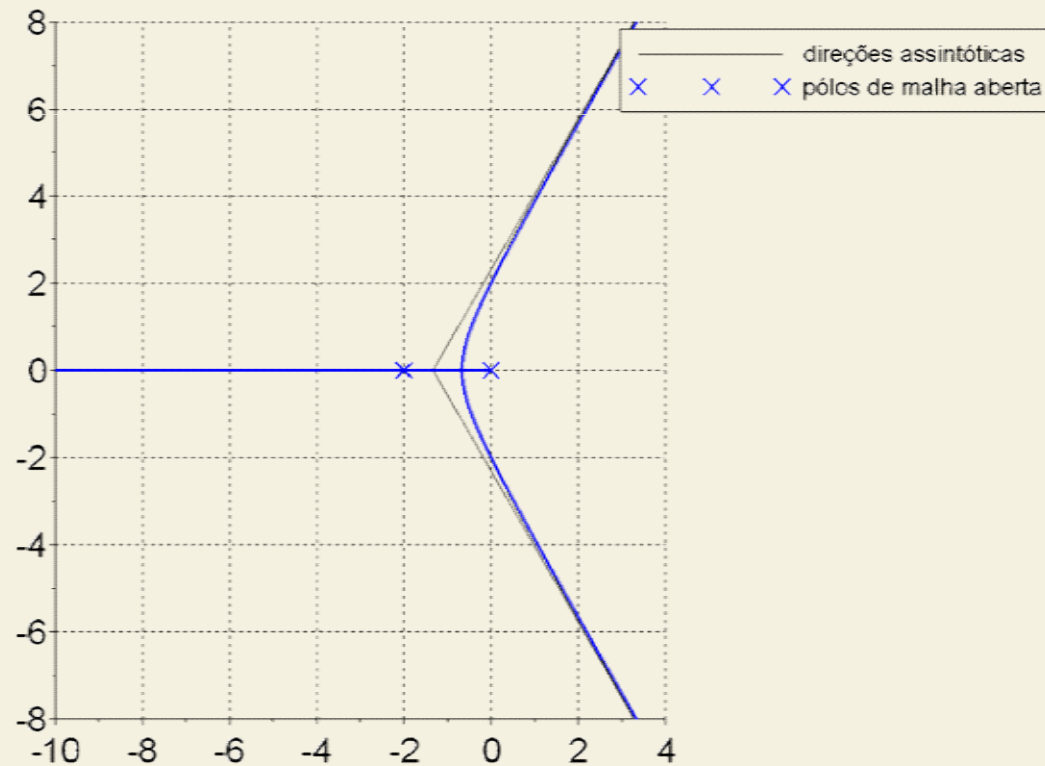
Estabilidade: exemplo

$$G(s) = \frac{K}{s(s+2)^2}$$

Limite da
estabilidade:

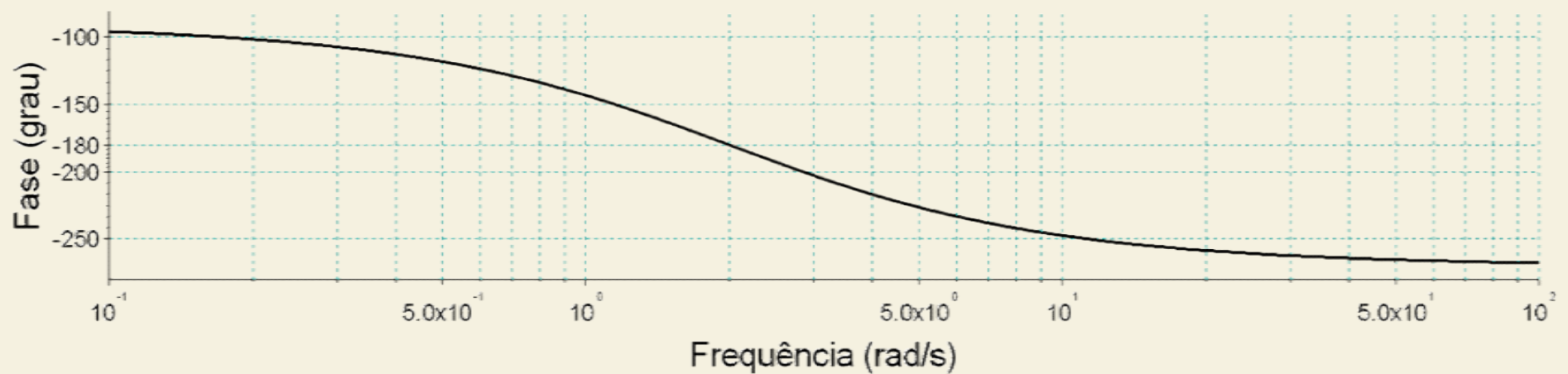
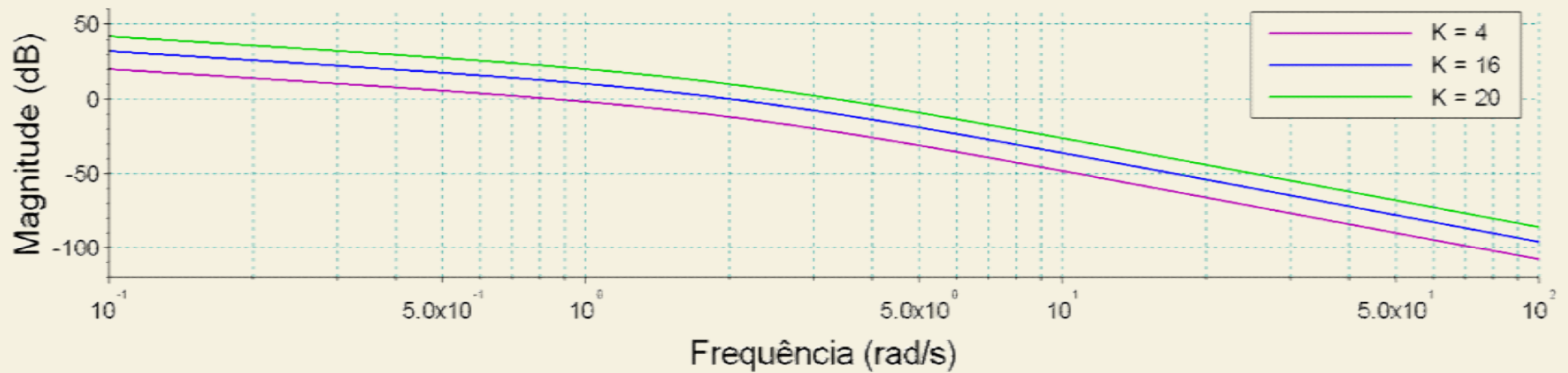
$$K = 16$$

$$\omega = 2 \text{ rad/s}$$



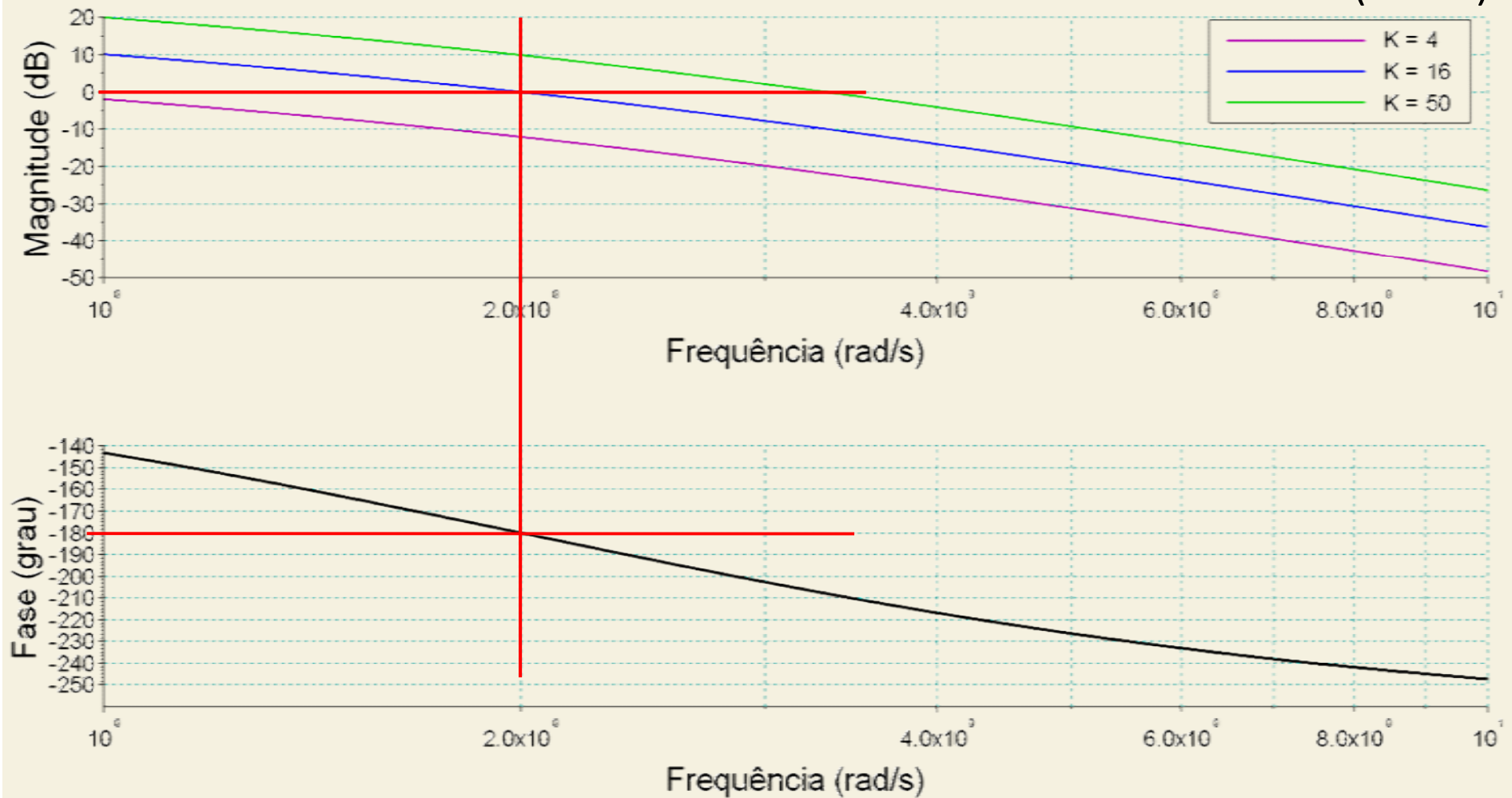
Estabilidade: exemplo

$$G(s) = \frac{K}{s(s+2)^2}$$



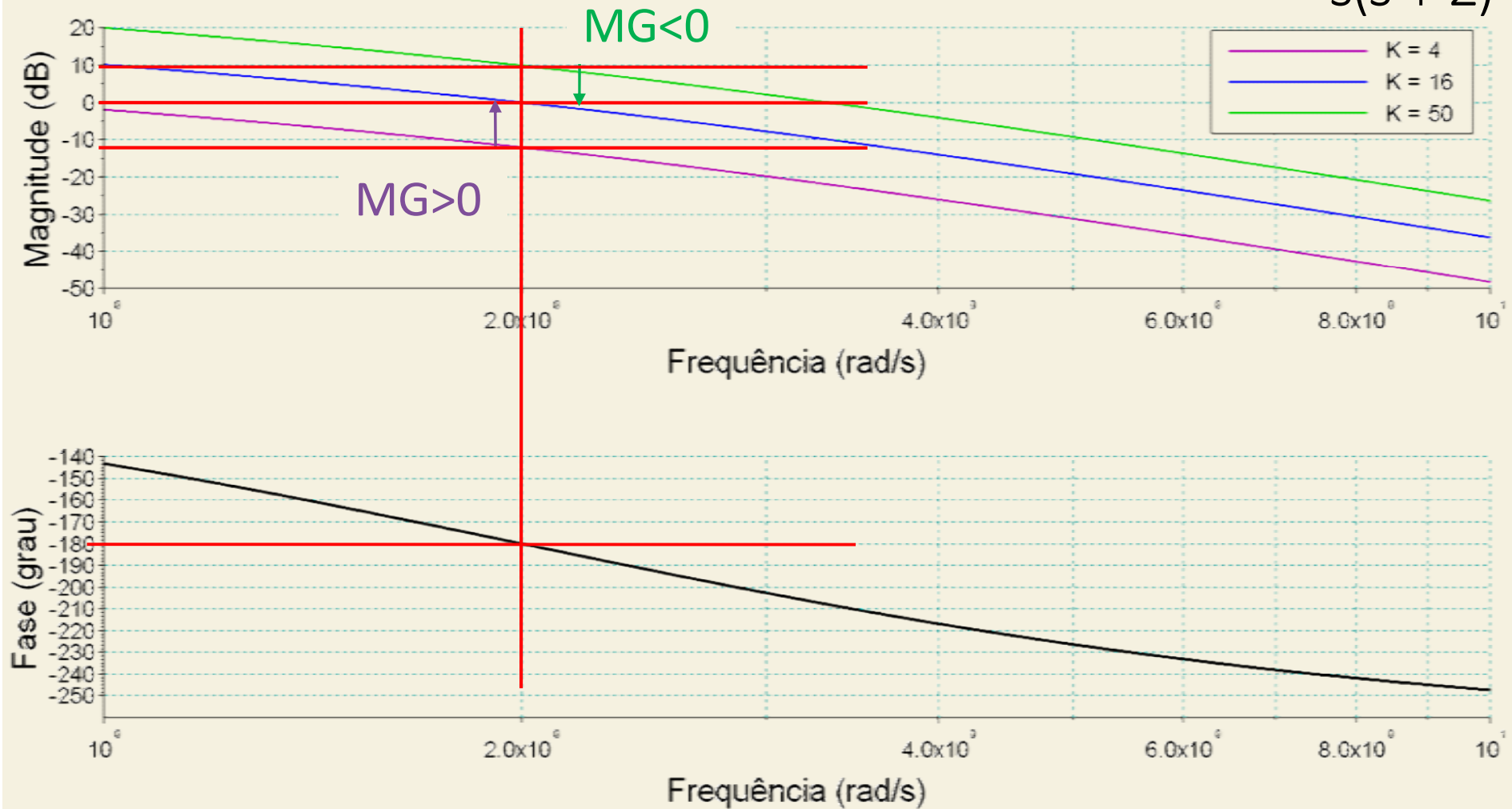
Estabilidade: exemplo

$$G(s) = \frac{K}{s(s+2)^2}$$



Estabilidade: exemplo

$$G(s) = \frac{K}{s(s+2)^2}$$



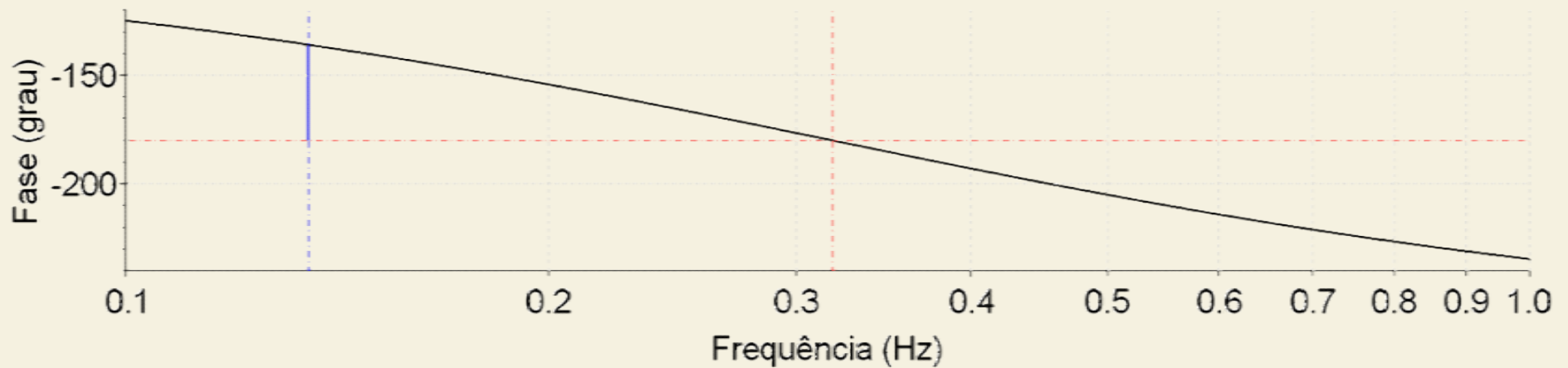
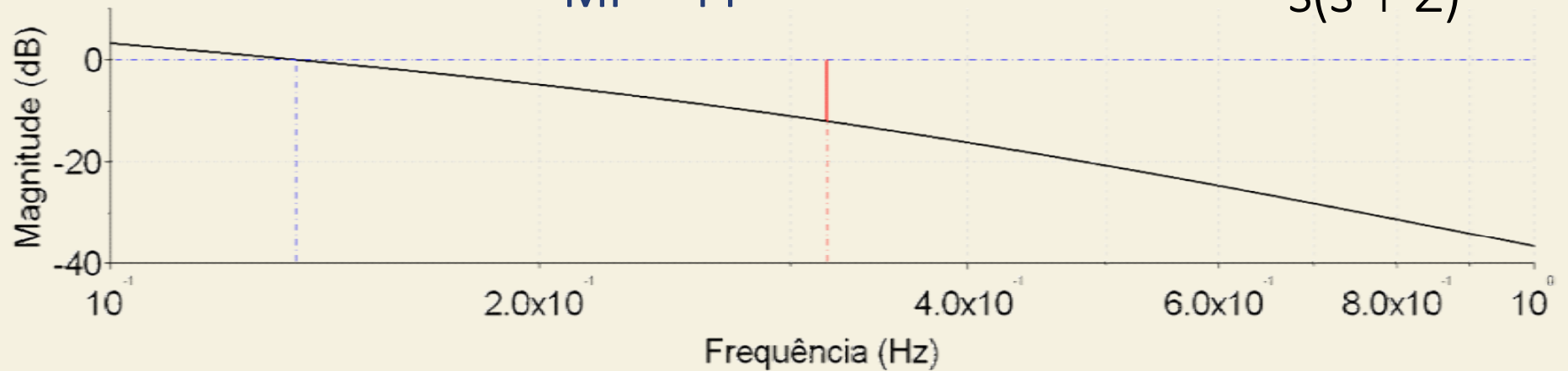
Estabilidade: exemplo

$$K = 4$$

$$MG = 4 \text{ (ou 12 dB)}$$

$$MF = 44^\circ$$

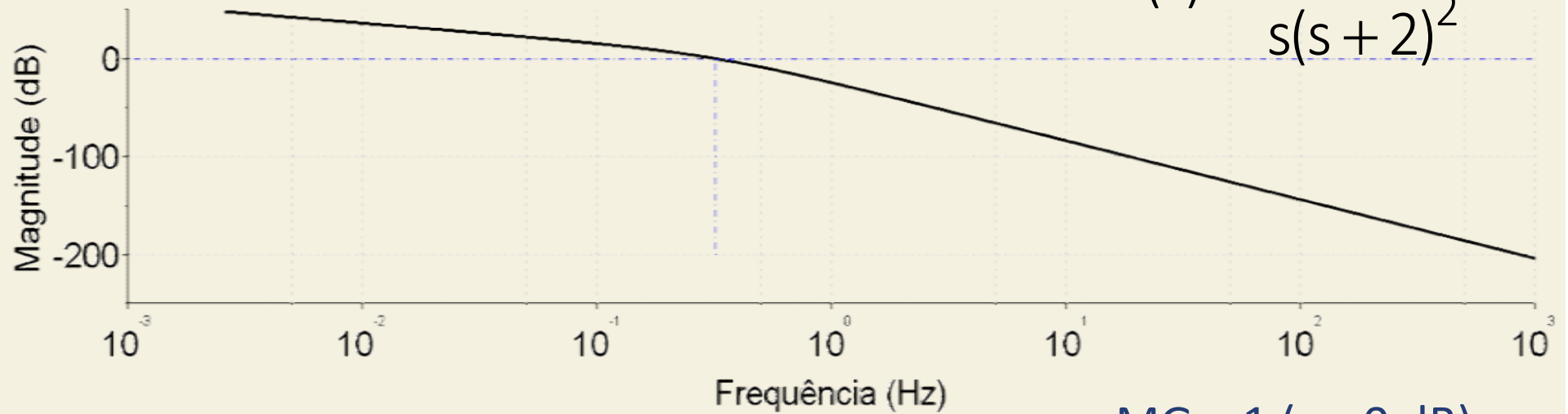
$$G(s) = \frac{K}{s(s+2)^2}$$



Estabilidade: exemplo

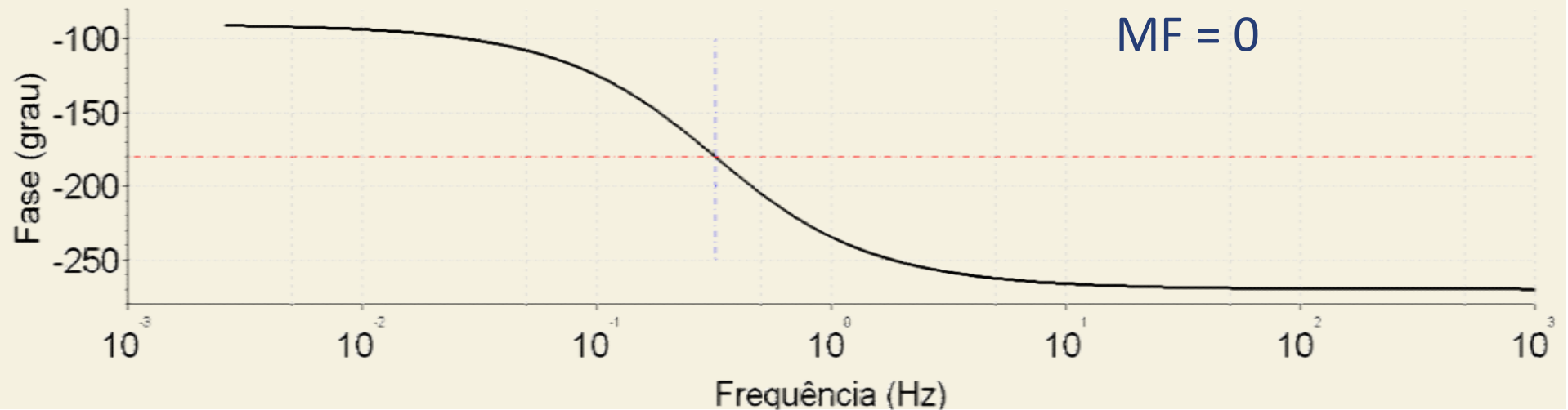
$K = 16$

$$G(s) = \frac{K}{s(s+2)^2}$$



$MG = 1$ (ou 0 dB)

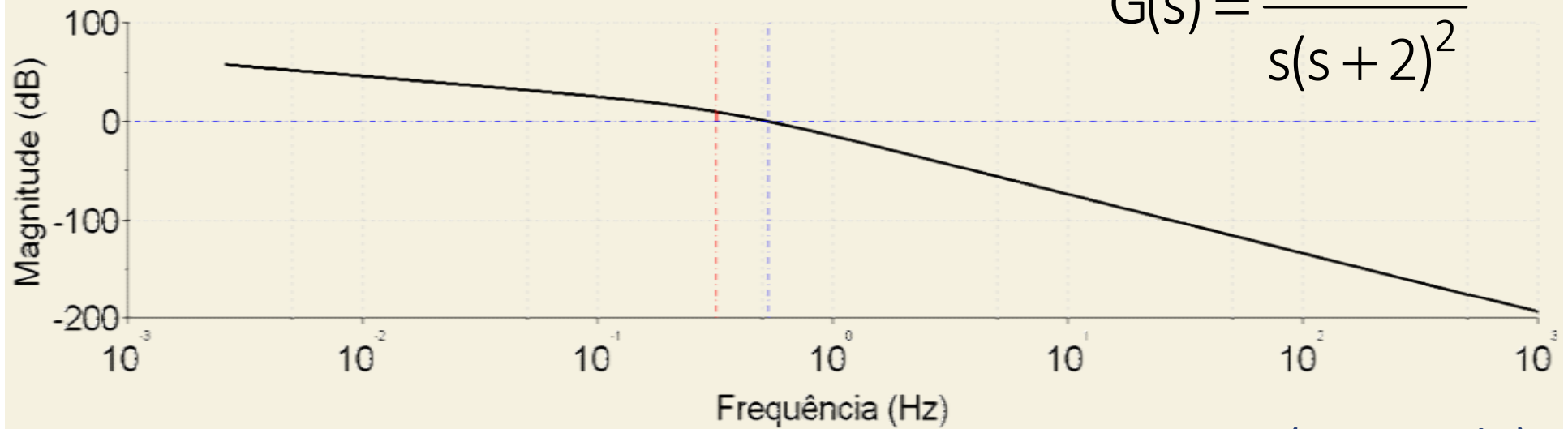
$MF = 0$



Estabilidade: exemplo

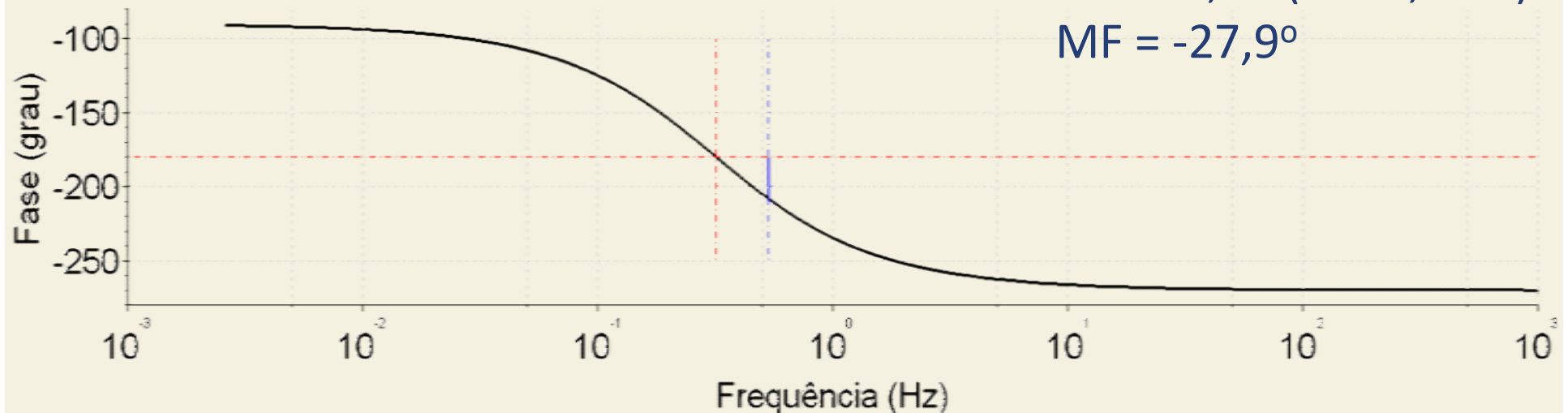
$K = 50$

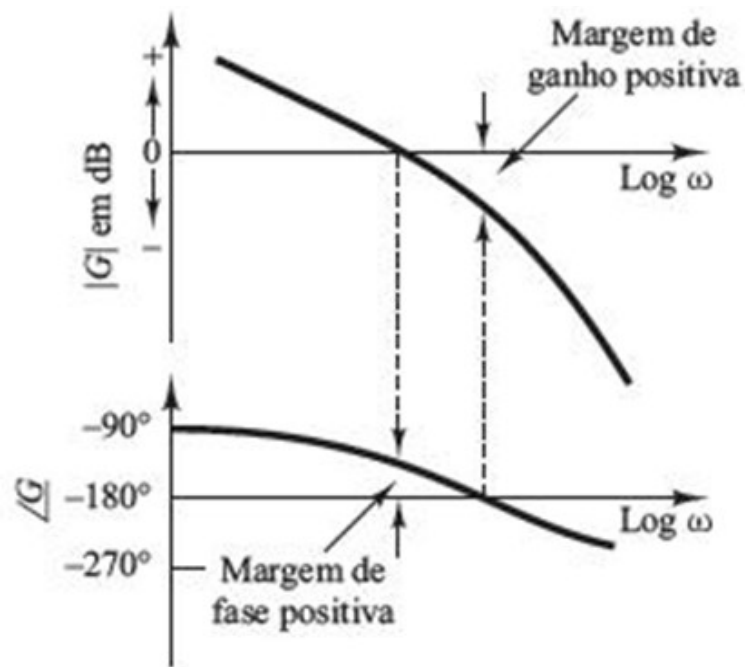
$$G(s) = \frac{K}{s(s+2)^2}$$



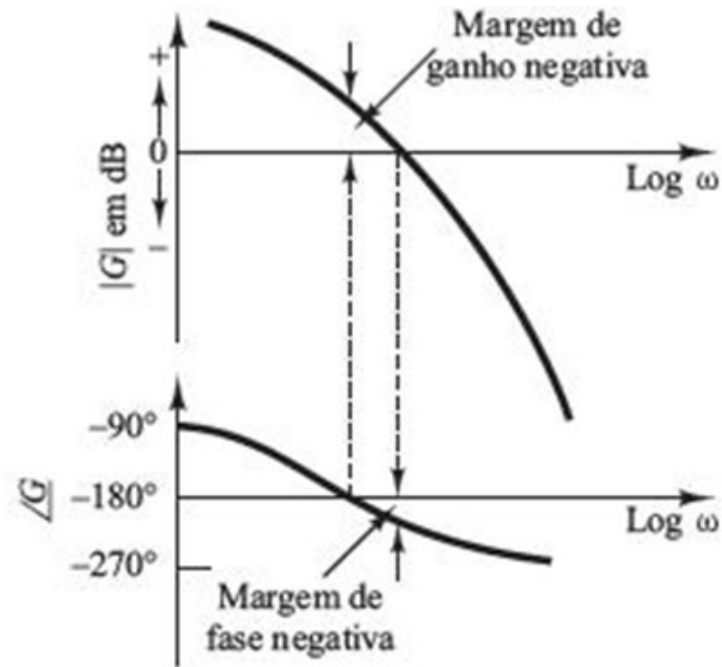
$MG = 0,32$ (ou $-9,9$ dB)

$MF = -27,9^\circ$





Sistema estável

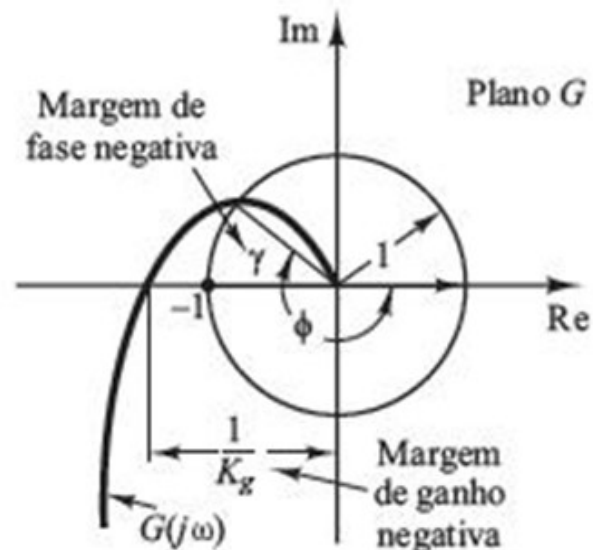


Sistema instável

(a)



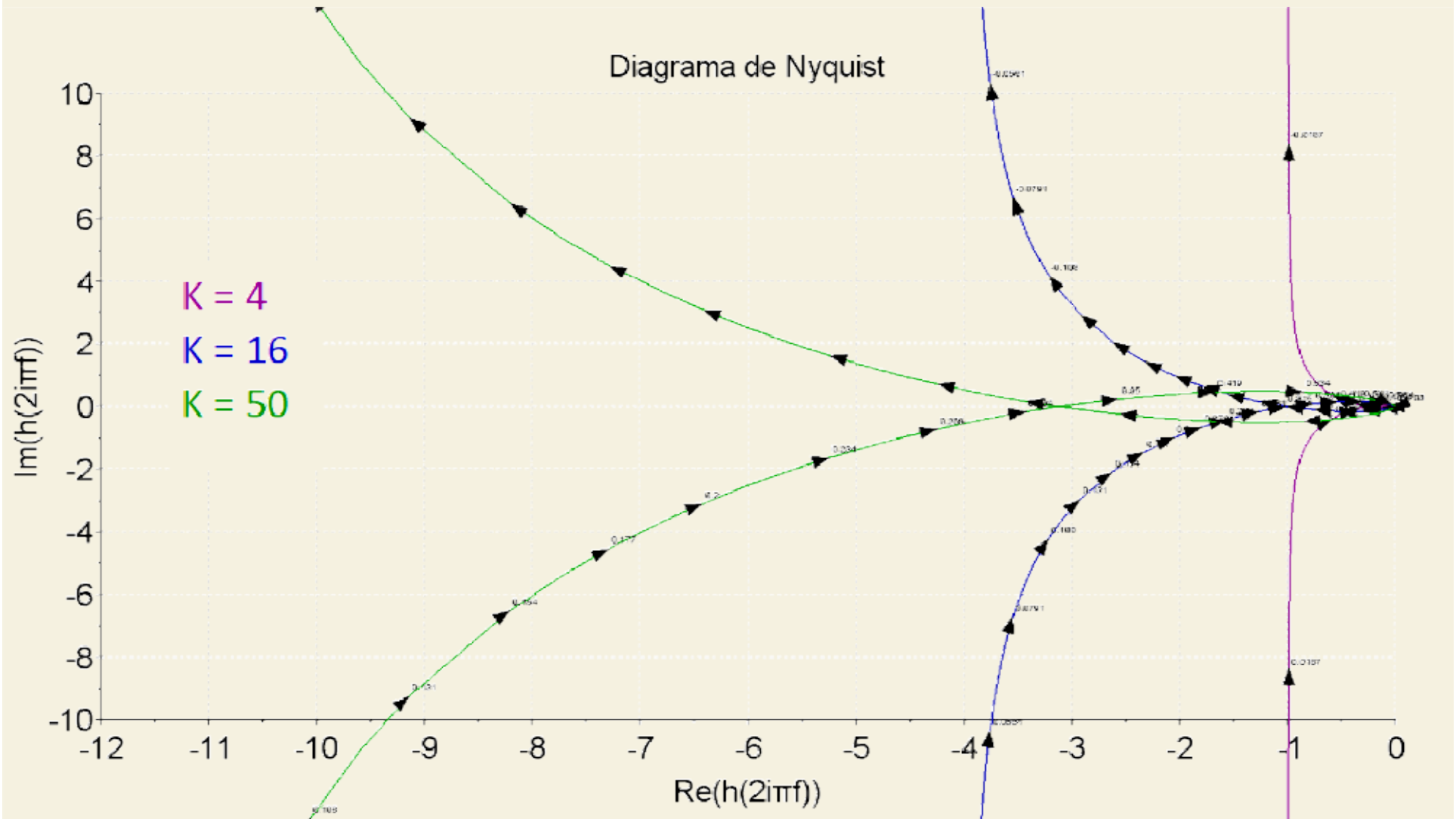
Sistema estável



Sistema instável

Estabilidade: exemplo

$$G(s) = \frac{K}{s(s+2)^2}$$

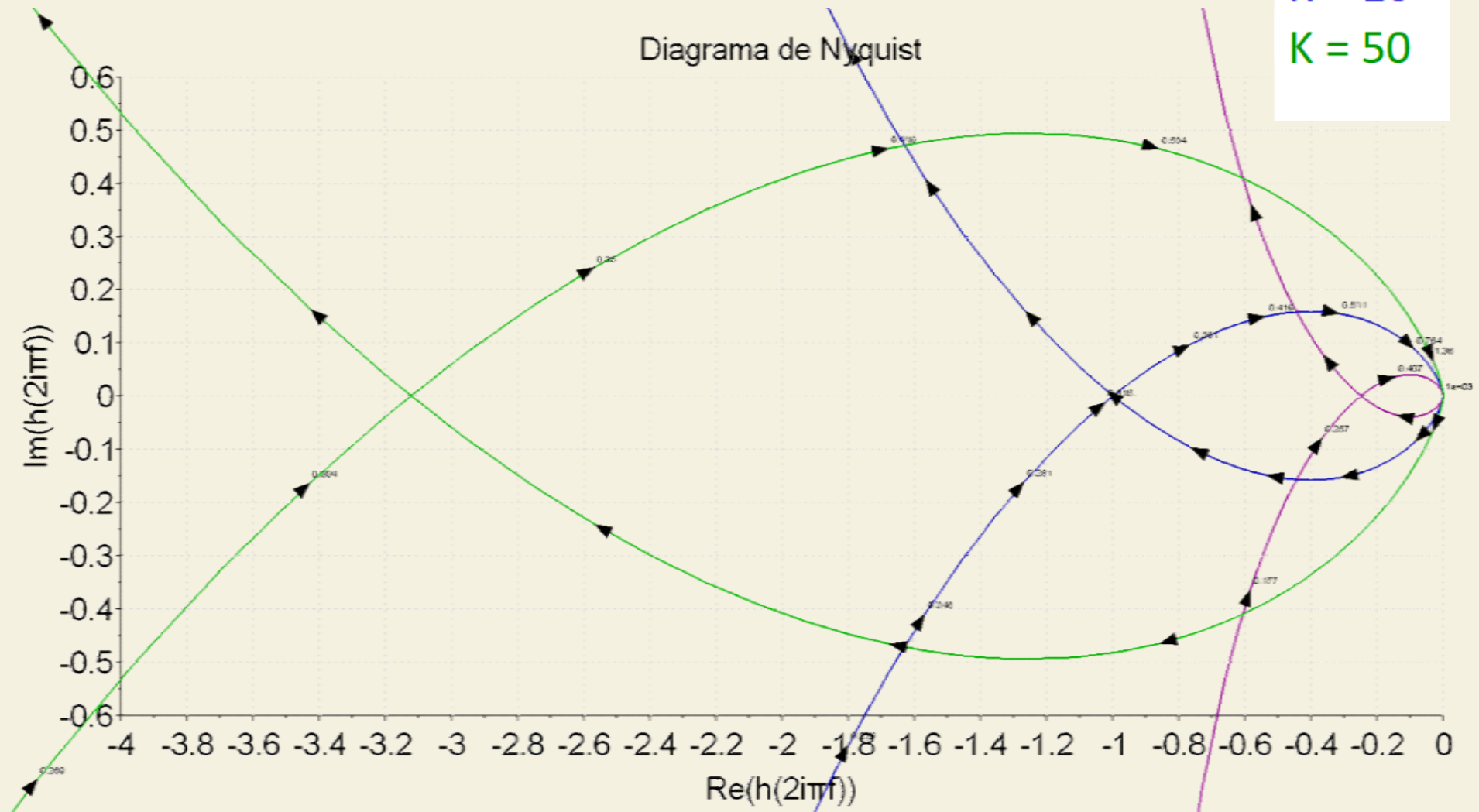


Estabilidade: exemplo

$$G(s) = \frac{K}{s(s+2)^2}$$

K = 4
K = 16
K = 50

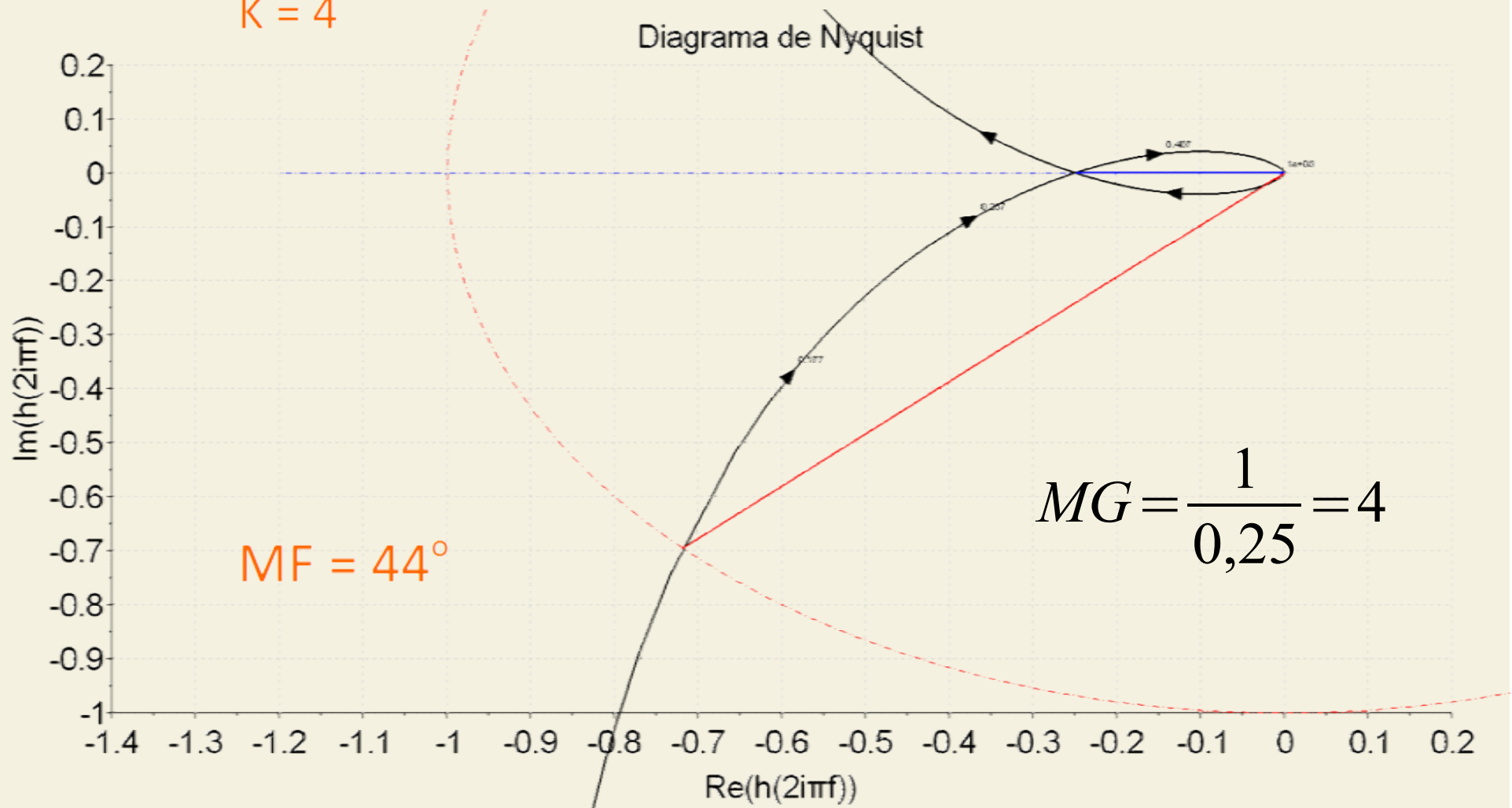
Diagrama de Nyquist



Estabilidade: exemplo

$$G(s) = \frac{K}{s(s+2)^2}$$

$$K = 4$$

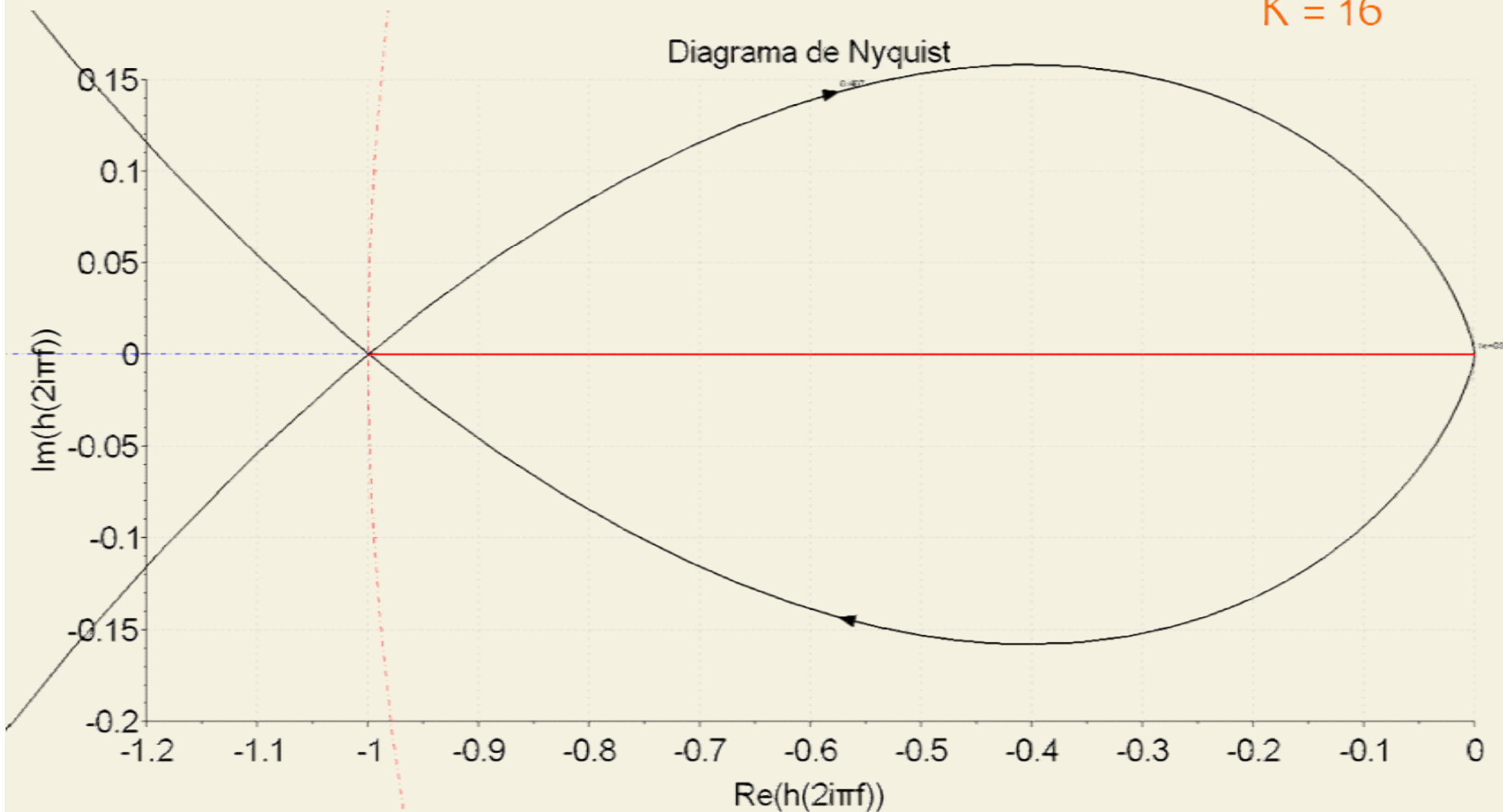


Estabilidad: ejemplo

$$G(s) = \frac{K}{s(s+2)^2}$$

K = 16

Diagrama de Nyquist



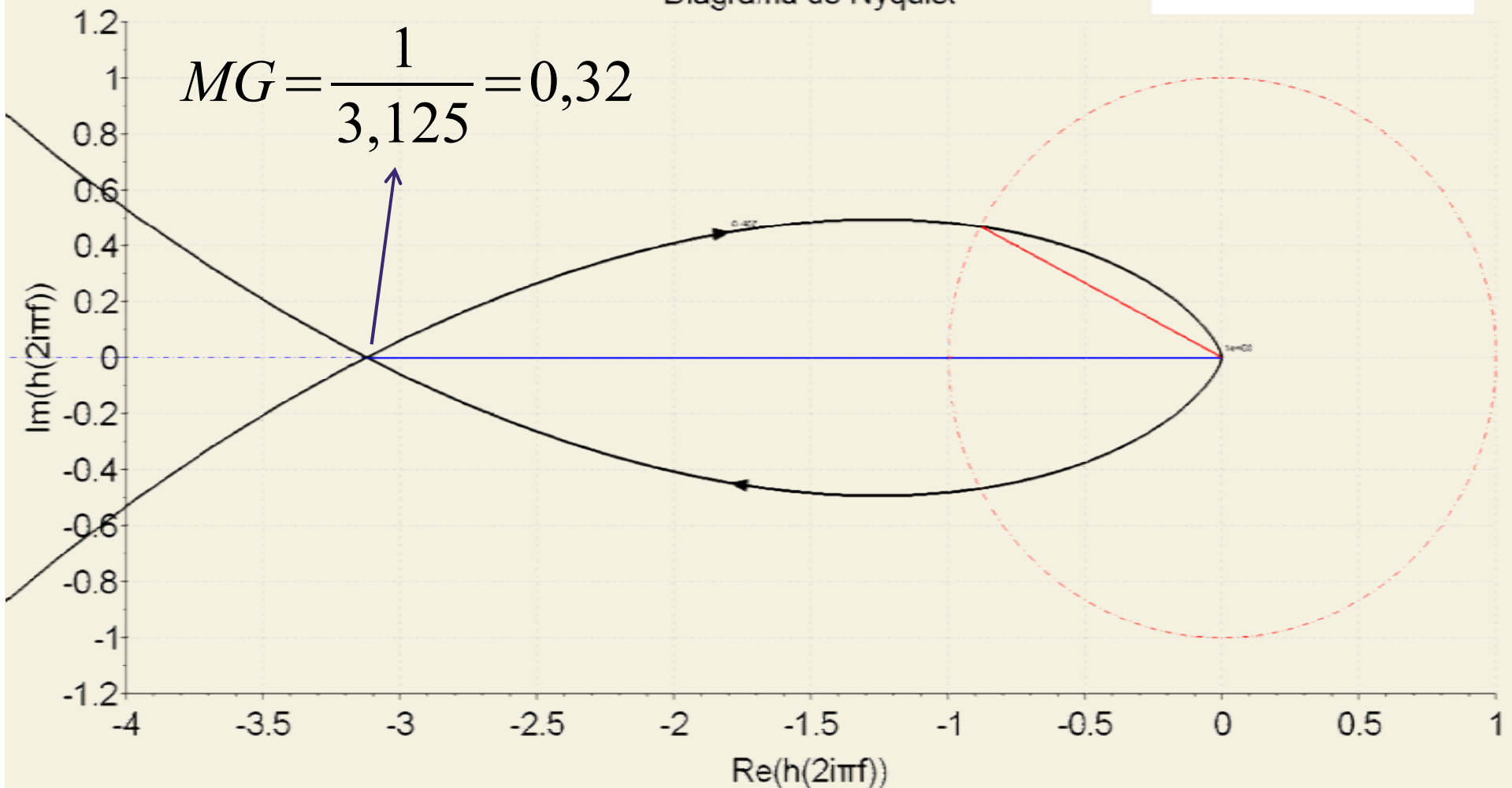
Estabilidade: exemplo

$$G(s) = \frac{K}{s(s+2)^2}$$

$$K = 50$$

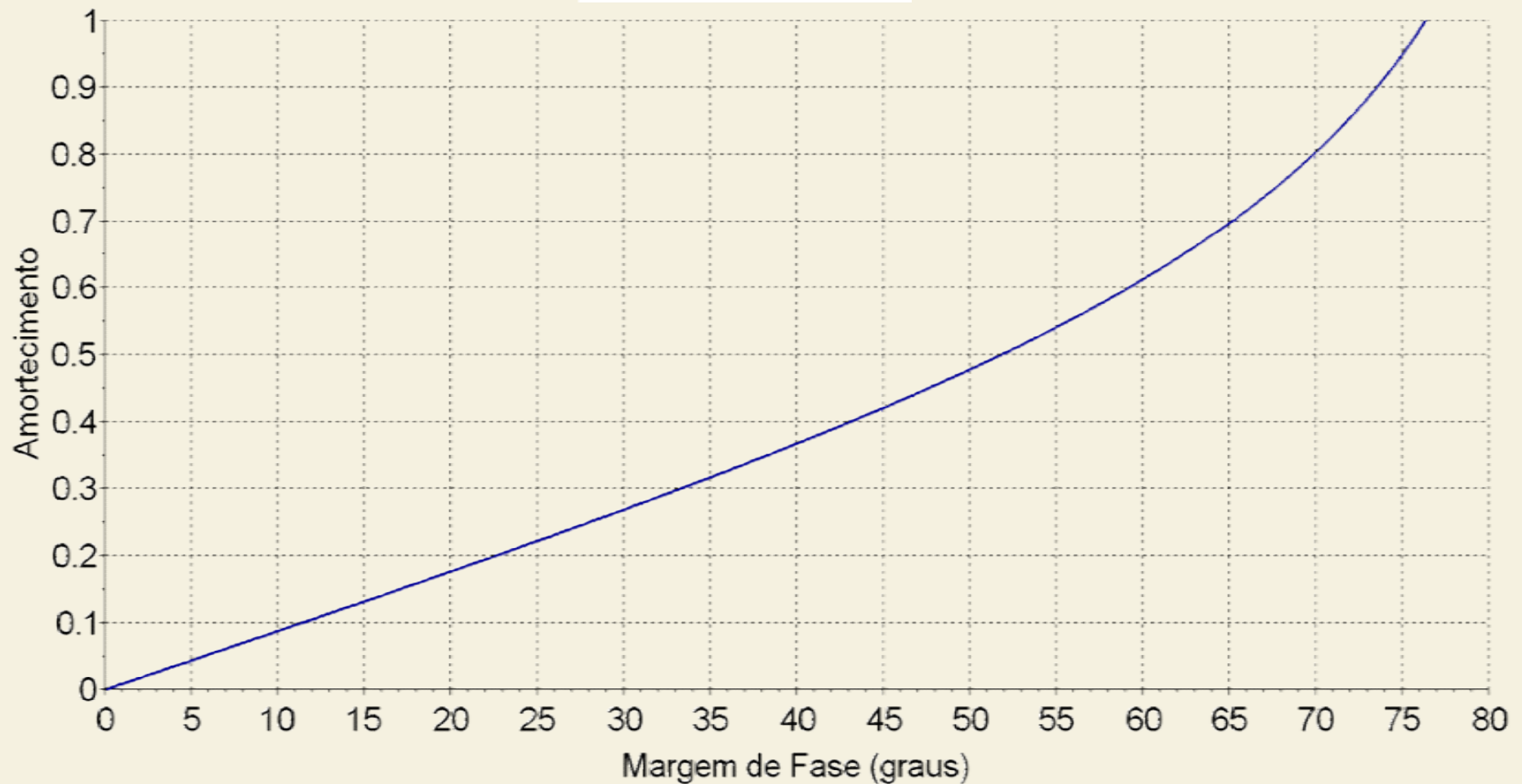
$$MF = -27,9^\circ$$

Diagrama de Nyquist



Margem de fase e amortecimento

$$MF \approx 100 \zeta$$



Exemplo: múltiplas frequências de cruzamento

Diagrama de Nyquist

