Aproximación de Butterworth

Resumen de formulas:

$$\left|H(j\omega)\right|_{dB} = A(\omega)\Big|_{dB} = 10.\log_{10}\left[1+\varepsilon^2\left(\frac{\omega}{\omega_p}\right)^{2n}\right][dB]$$

De donde para $\omega = \omega_p$ se puede despejar:

$$A(\omega_p)\Big|_{dB} = 10.\log_{10}\left(1+\varepsilon^2\right) = A_{\max} \Rightarrow \boxed{\varepsilon = \sqrt{10^{0,1.A_{\max}}-1}}$$

Conociendo ε, ω_p, ω_s y $A_{\min}$ despejamos el orden n:

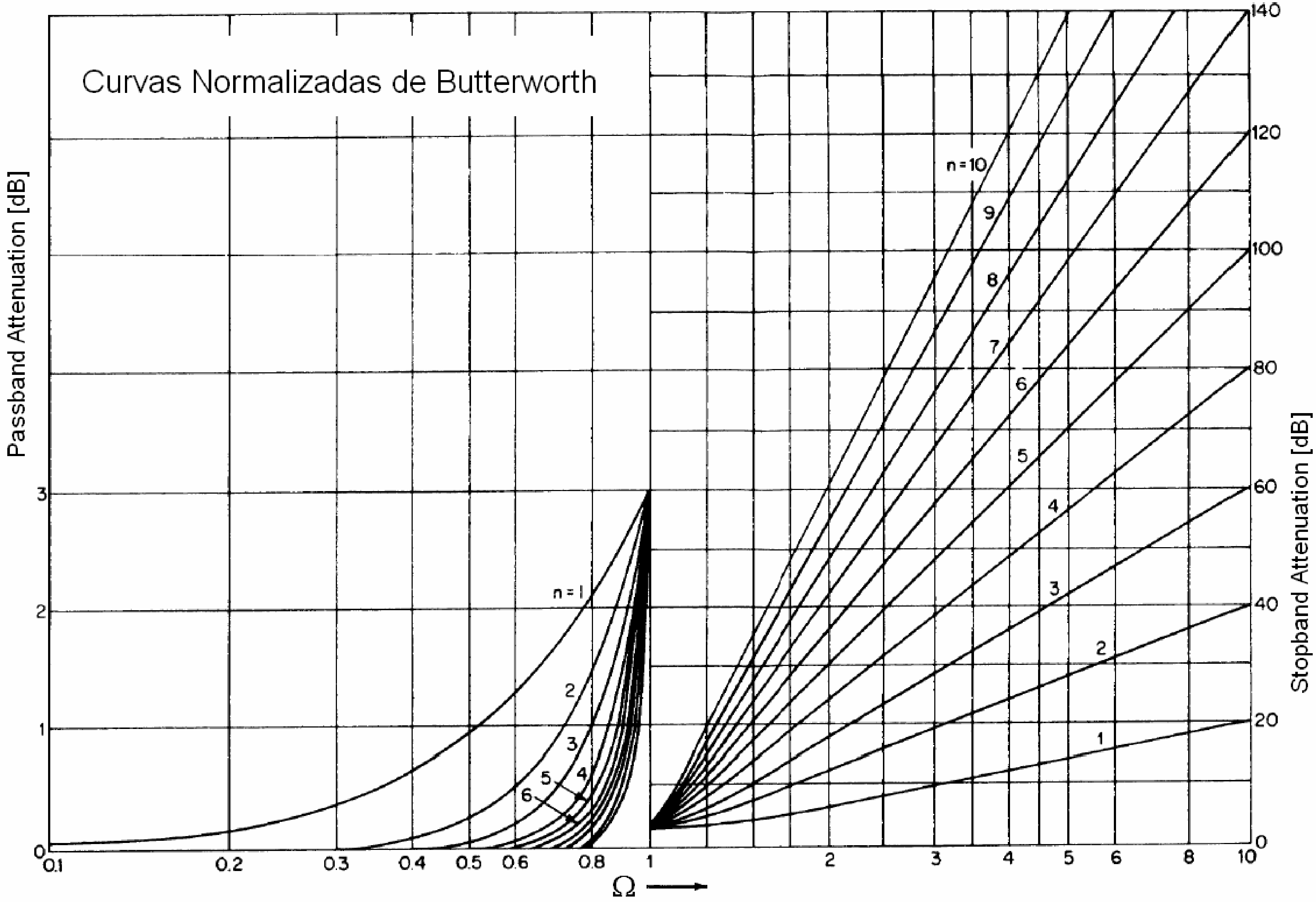
$$A(\omega_p)\Big|_{dB} = 10.\log_{10}\left[1+\varepsilon^2\left(\frac{\omega_s}{\omega_p}\right)^{2n}\right] = A_{\min} \quad \Rightarrow \quad \boxed{n = \frac{\log_{10}\left(\dfrac{10^{0,1.A_{\min}}-1}{\varepsilon^2}\right)}{\log_{10}\left(\dfrac{\omega_s}{\omega_p}\right)^2}}$$

Para simplificar los cálculos de diseño es conveniente normalizar para independizarnos de ε y ω_p.

$$\boxed{\Omega = \varepsilon^{1/n}\left(\frac{\omega}{\omega_p}\right)} \quad \Rightarrow \quad A(\Omega) = 10.\log_{10}(1+\Omega^{2n})$$

Se nota que si $\Omega >> 1$ entonces $A(\Omega) \rightarrow 20.n.\log_{10}(\Omega)$

n	***Polinomios de Butterworth Normalizados - H(S)***
1	S + 1
2	S^2 + 1.414 S + 1
3	(S^2 + S + 1).(S + 1)
4	(S^2 + 0.765 S + 1).(S^2 + 1.848 S + 1)
5	(S + 1).(S^2 + 0.618 S + 1).(S^2 + 1.618 S + 1)
6	(S^2 + 0.517 S + 1).(S^2 + 1.414 S + 1).(S^2 + 1.932 S + 1)
7	(S + 1).(S^2 + 0.445 S + 1).(S^2 + 1.247 S + 1).(S^2 + 1.802 S + 1)
8	(S^2 + 0.39 S + 1).(S^2 + 1.111 S + 1).(S^2 + 1.663 S + 1).(S^2 + 1.962 S + 1)


Curvas Normalizadas de Butterworth
Passband Attenuation [dB]
Stopband Attenuation [dB]
n = 1
2
3
4
5
6
n = 10
9
8
7
6
5
4
3
2
1
0
1
2
3
0
20
40
60
80
100
120
140
0.1
0.2
0.3
0.4
0.5
0.6
0.8
1
2
3
4
5
6
8
10
Ω