AN EFFECTIVE SCHEME FOR NOISE CANCELLATION IN MICROWAVE AMPLIFIERS.

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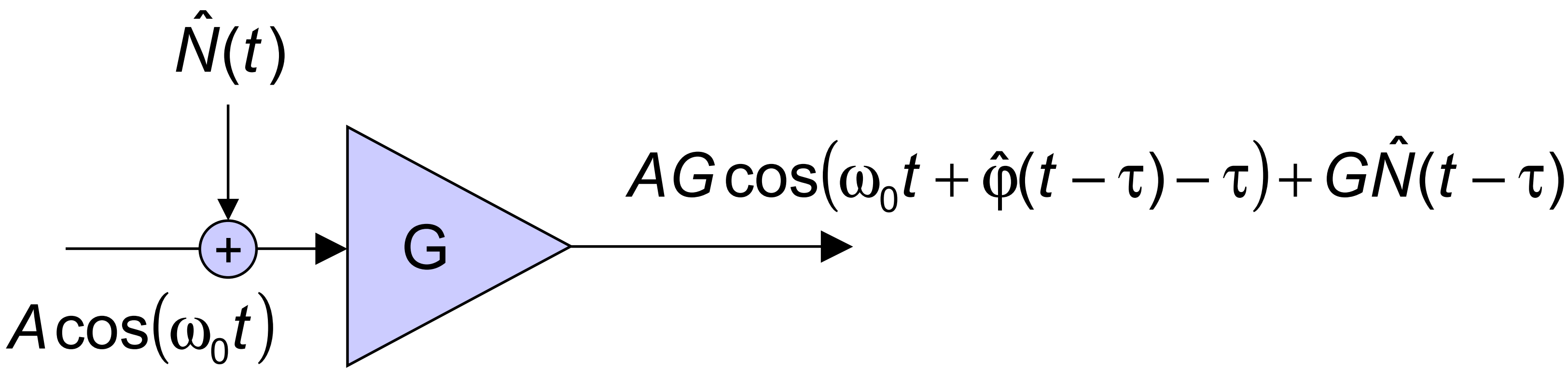
FCS/EFTF, May 5th-9th 2003 Tampa, FL

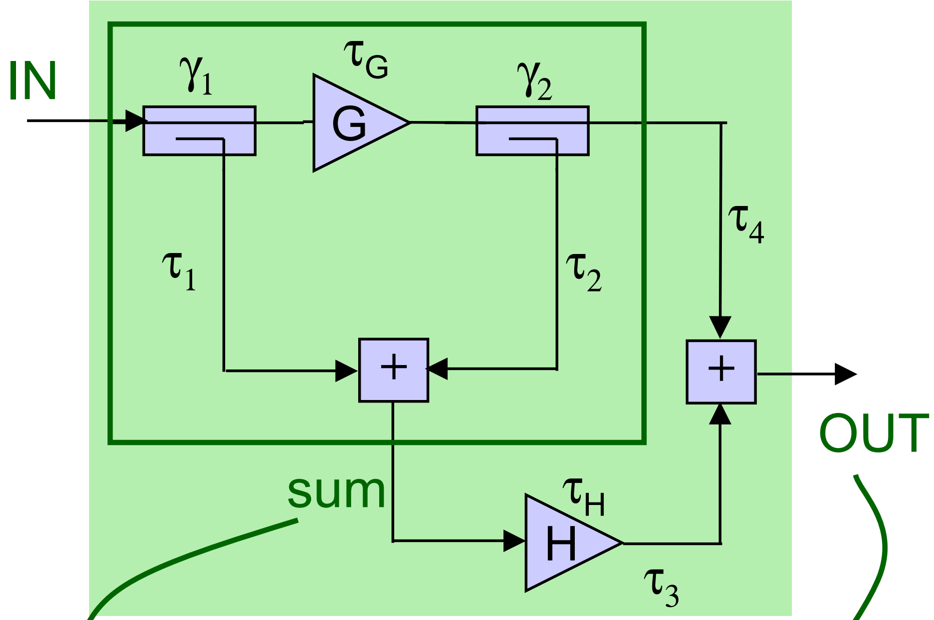
Amplifier noise



G amplitude gain

$\hat{\varphi}(t)$ $\hat{N}(t)$	multiplicative & additive	noise processes generated by the amplifier

The conceptual scheme



$$\underline{sum} = A\gamma_1\hat{\varphi}_G\sin(\omega_0 t - \tau) + \gamma_1\hat{N}_G(t-\tau)$$

- Ideal input signal

$$A\cos(\omega_0 t)$$

- Noise processes

$$\hat{\varphi}_G, \hat{\varphi}_H, \hat{N}_G, \hat{N}_H$$

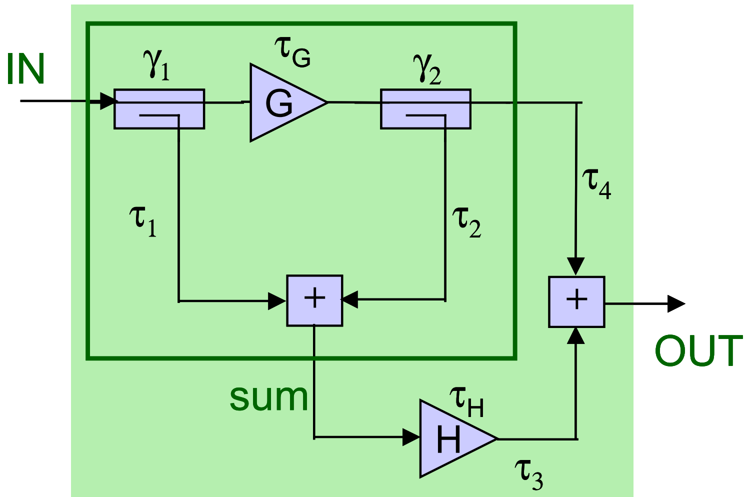
- Time (phase) delays

$$\tau_i \quad i = 1..4$$

$$\underline{OUT} = AG\cos(\omega_0 t - \tau) + H\hat{N}_H(t - \tau')$$

no multiplicative noise!

Features of ideal system



Carrier cancellation conditions

$$\begin{cases} \tau_2 + \tau_G = \tau_1 \pm \pi / \omega_0 \\ G\gamma_2 = \gamma_1 \end{cases}$$

Noise cancellation conditions

$$\begin{cases} \tau_1 + \tau_H + \tau_3 = \tau_4 + \tau_G \\ \gamma_1 H = G \quad \leftrightarrow \quad \gamma_2 H = 1 \end{cases}$$

Amplifier phase variations with temperature are a source of fluctuations in cancellation conditions.

Non-ideal cancellation conditions - I

- Imperfect carrier cancellation

$$\begin{cases} \tau_2 + \tau_G = \tau_1 + \Delta\tau_c \pm \pi/\omega_0 \\ G\gamma_2 = \gamma_1 + \Delta\alpha_c \end{cases}$$

$$sum = A(\gamma_1 + \Delta\alpha_c)\,\hat{\varphi}_G \sin(\omega_0 t - \tau) - \gamma_1 \hat{N}_G(t-\tau) - \underbrace{A\Delta\alpha_c \cos\left(\omega_0 t - \tau - \gamma_1 \frac{\Delta\tau_c}{\Delta\alpha_c}\right)}_{\text{residual carrier}}$$

- Imperfect noise cancellation

$$\begin{cases} \tau_1 + \tau_3 + \tau_H = \tau_4 + \tau_G + \Delta\tau_n \\ \gamma_1 H = G + \Delta\alpha_n \end{cases}$$

$$OUT = AG(1 - \underbrace{\Delta\tau_n \hat{\varphi}_G}_{\text{AM noise}})\cos\left(\omega_0 t - \tau + \underbrace{\frac{\Delta\alpha_n}{G}\hat{\varphi}_G}_{\text{residual multiplicative phase noise}}\right) + \hat{H}N_H(t-\tau) - \underbrace{\Delta\alpha_n \hat{N}_G(t-\tau)}_{\text{excess additive noise}}$$

Non-ideal cancellation conditions - II

- Both cancellations are imperfect

$$OUT = AG\left[1+\left(\Delta\tau_c+\Delta\tau_n\right)\hat{\varphi}_G\right]\cos\left[\omega_0 t+\frac{\Delta\alpha_n}{G}\hat{\varphi}_G+\frac{\Delta\alpha_c}{\gamma_1}\hat{\varphi}_H-\tau\right]$$

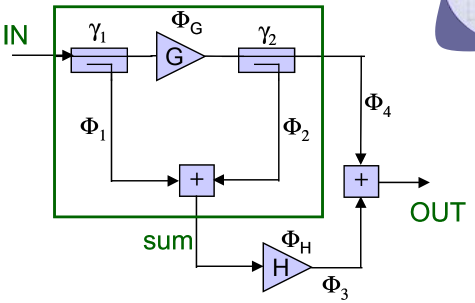
$$+H\hat{N}_H(t-\tau)-\Delta\alpha_n\hat{N}_G(t-\tau)$$

AM noise: $\left(\Delta\tau_c+\Delta\tau_n\right)\hat{\varphi}_G$

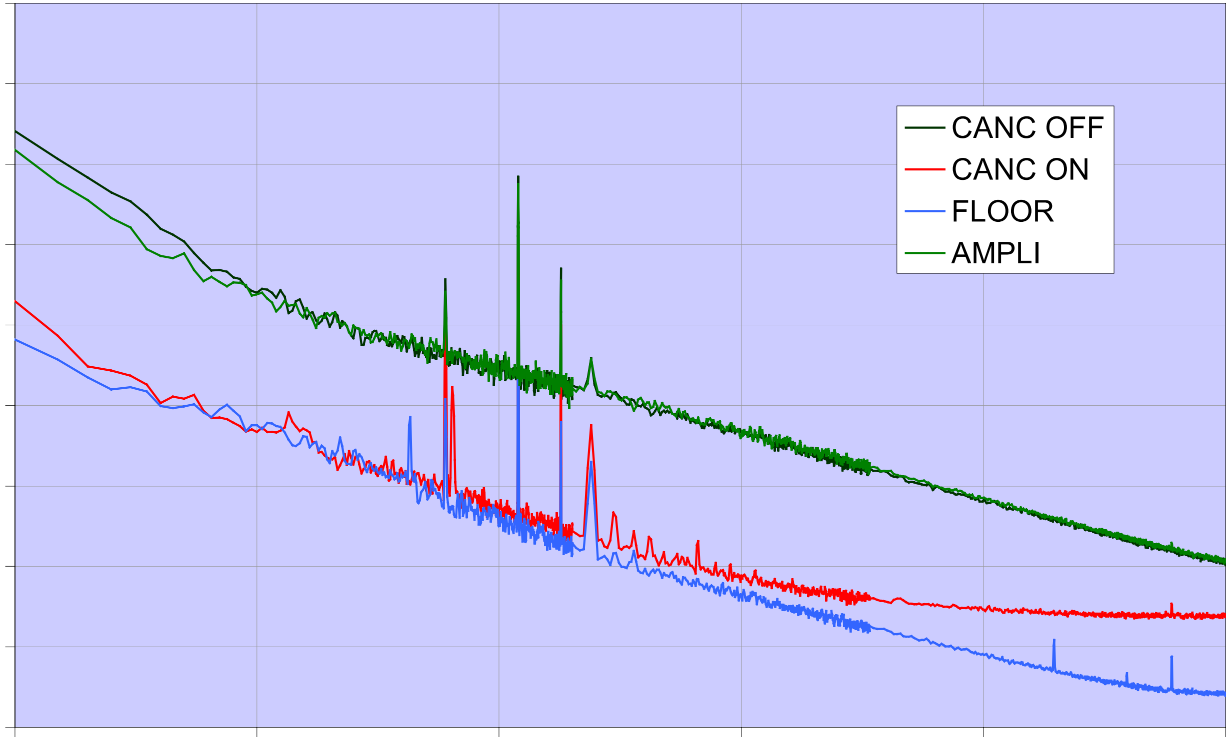
residual *multiplicative* phase noise: $\frac{\Delta\alpha_n}{G}\hat{\varphi}_G+\frac{\Delta\alpha_c}{\gamma_1}\hat{\varphi}_H$

residual *additive* phase noise: $\Delta\alpha_n\hat{N}_G(t-\tau)$

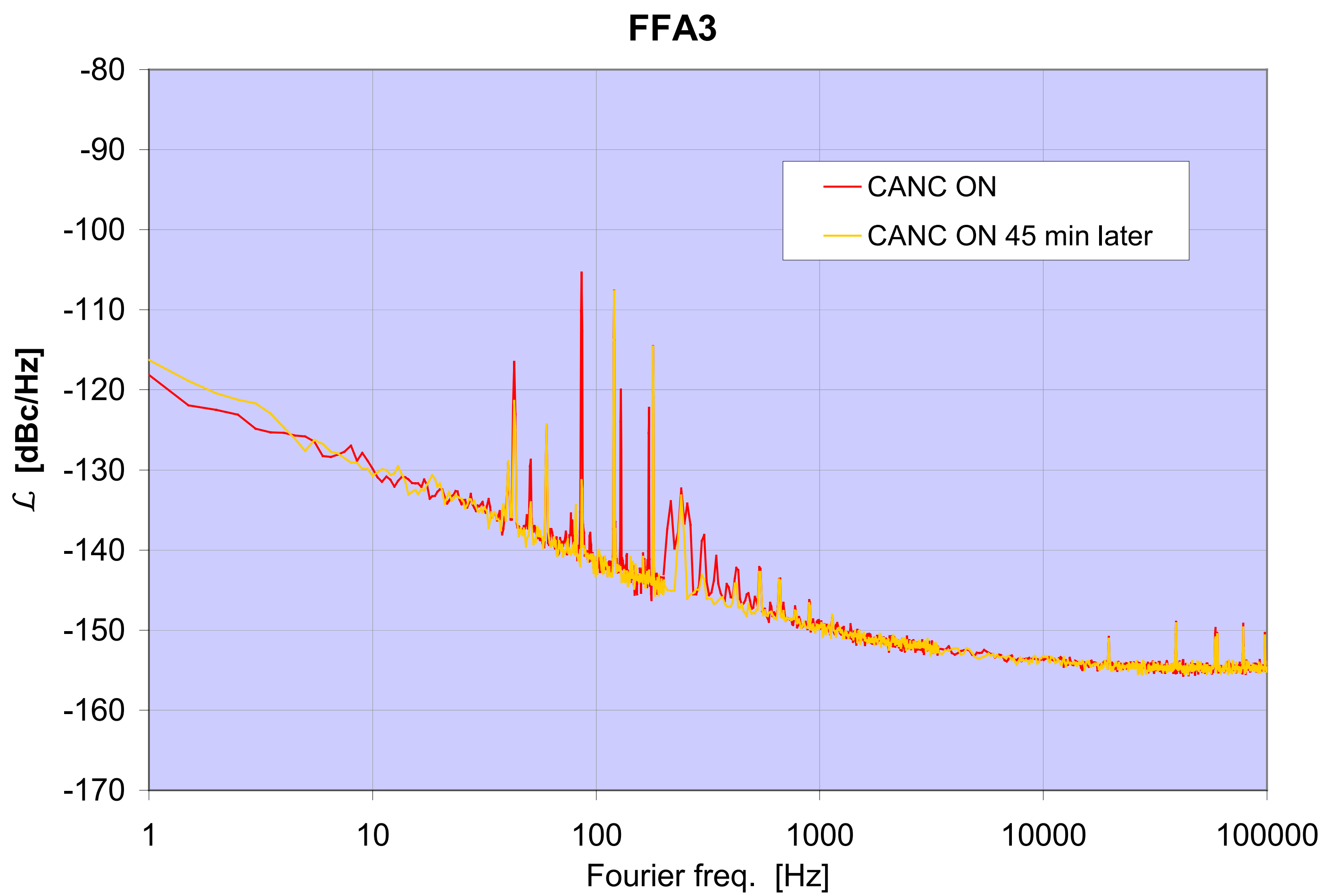
10G system



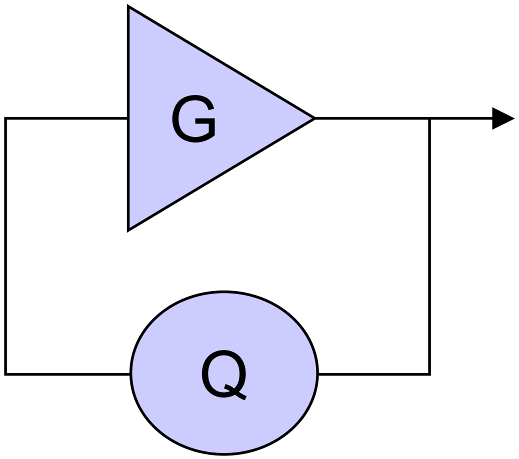
Gain=21 dB P_{out}= 11 dBm



Cancellation stability over time



Oscillator application



✐Leeson model

Given amplifier with

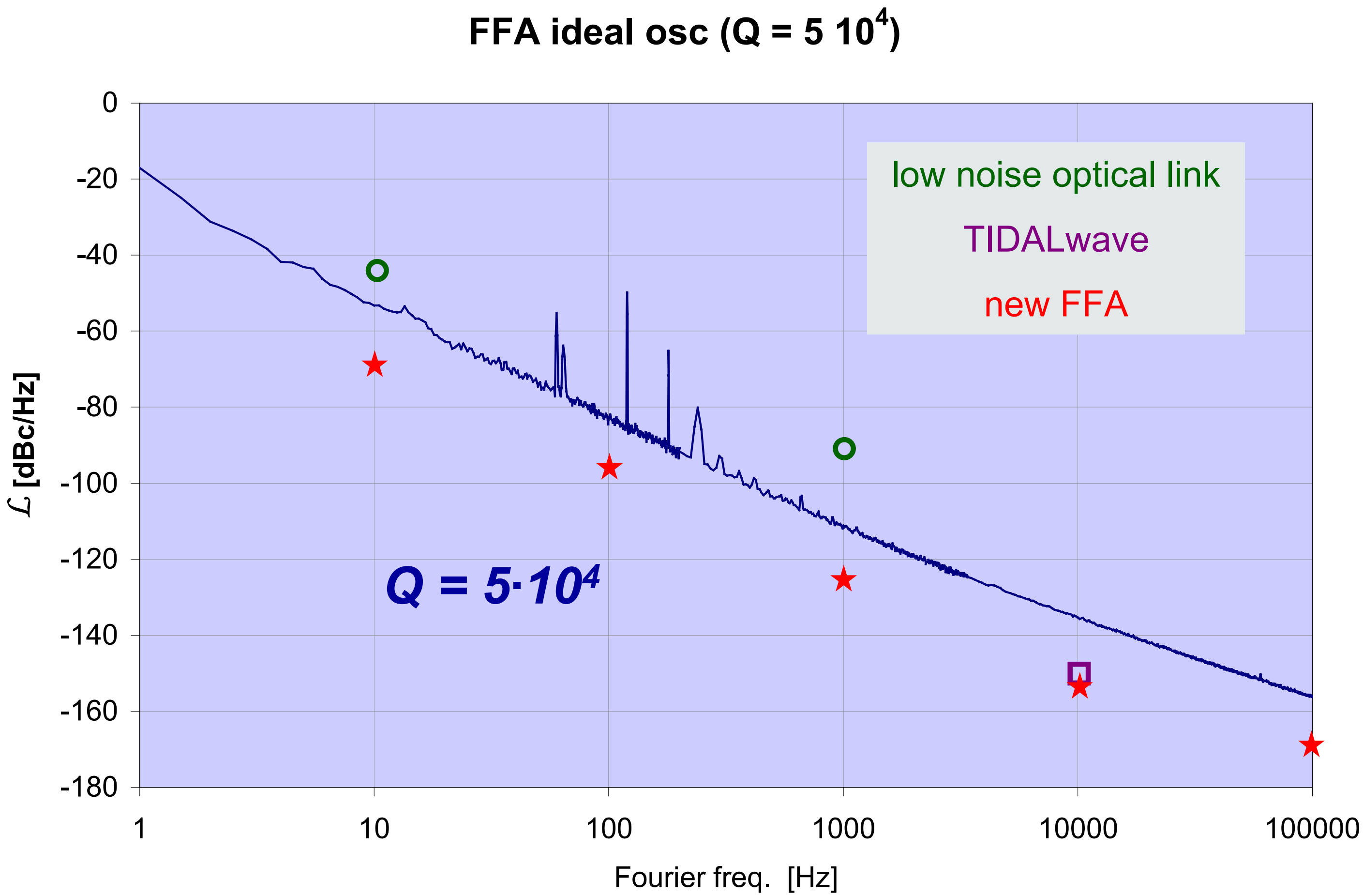
$$S_\varphi^{amp}(f)$$

and resonator with

$$Q = 5 \cdot 10^4$$

$$\Rightarrow \quad S_\varphi^{osc}(f) = \frac{\nu_0^2}{4 \cdot 5 \cdot 10^4 f^2} S_\varphi^{amp}(f)$$

Comparisons



Conclusions and future work

- cross-correlation phase noise measurement system
- implementation of cancellation control loops
- what happens to AM?
- limitations in additive noise cancellation
- limitations due to cross-talk
- implementation in oscillator loop and operation in compressed regime
- higher power regime