Novel Parametric-effect MEMS Amplifiers/Transducers for Sonar Applications

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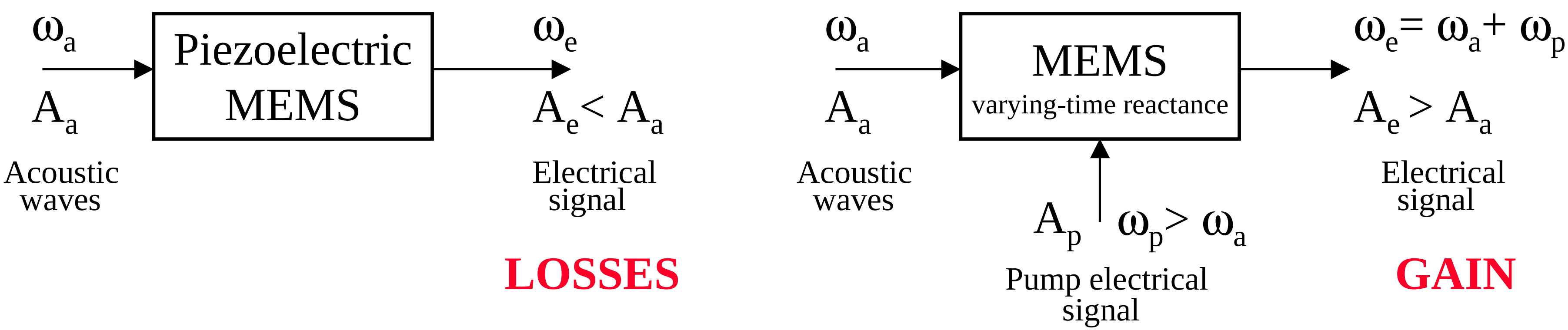
Idea: Use Parametric Effects in MEMS

Transducer　　　　Parametric Amplifier Transducer



First mechanical parametric amplifier using MEMS

Advantages:
- gain at the transducer level
- low-noise (no 1/f noise)
- silicon technology: high integration, low cost
- wide bandwidth (kHz - MHz)

Parametric Effects

- have been largely used in **1960's**: up and down frequency conversion, amplification **at microwave frequencies**.

- are based on **time varying properties** of a capacitor or inductor (Manley-Rowe Equations).

- allow to **transfer power** from the pump frequency (ω_p) to the input signal frequency (ω_s) or to the up-conversion frequency (ω_u) ⇨ **GAIN**.

- The source of power for a usual transducer amplifier is a **dc supply**, for a parametric amplifier: the **source of power is the pump electrical signal (ω_p), which is a higher frequency** than the input signal (ω_s) .

Amplifiers / up-converters
Gain - Bandwidth

Time varying capacitor: $C(t) = C_0 + C_1.\cos(\omega_p t) + C_2.\cos(2\omega_p t) + \ldots$ with $C_1/C_0 = 0.5 - 1.0$

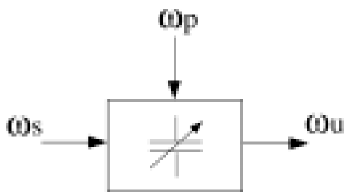
⇨ currents and voltages are generated at all combination frequencies:

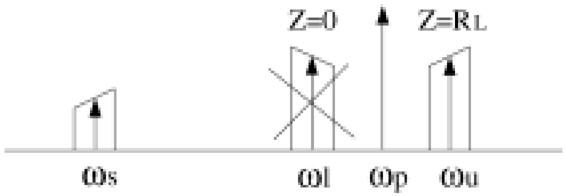
$f_{n,m} = n.f_s \pm m.f_p \quad (n,m = -\infty \ldots \infty)$

Practically, we will keep only certain combinations of frequencies.

Noninverting up-converter

$f_u = f_p + f_s$





Equivalent input conductance is positive
⇨ **Stable** amplifier and possible matching

Max. gain and bandwidth at matched conditions:

$$g_u = g_s = 2\pi C_1.\sqrt{f_s \cdot (f_p + f_s)}$$

Manley and Rowe: $\frac{P_s}{f_s} + \frac{P_u}{f_u} = 0$

Transducer and Power Gain: $\frac{P_u}{P_s} = \frac{f_p + f_s}{f_s} > 1$

Bandwidth: $B = \frac{C_1}{C_0} \cdot \sqrt{2.f_s.(f_p + f_s)}$