# A 0.8-1.8 GHz Wideband Low Noise Amplifier with Capacitive Feedback

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# Necessity of multi standard



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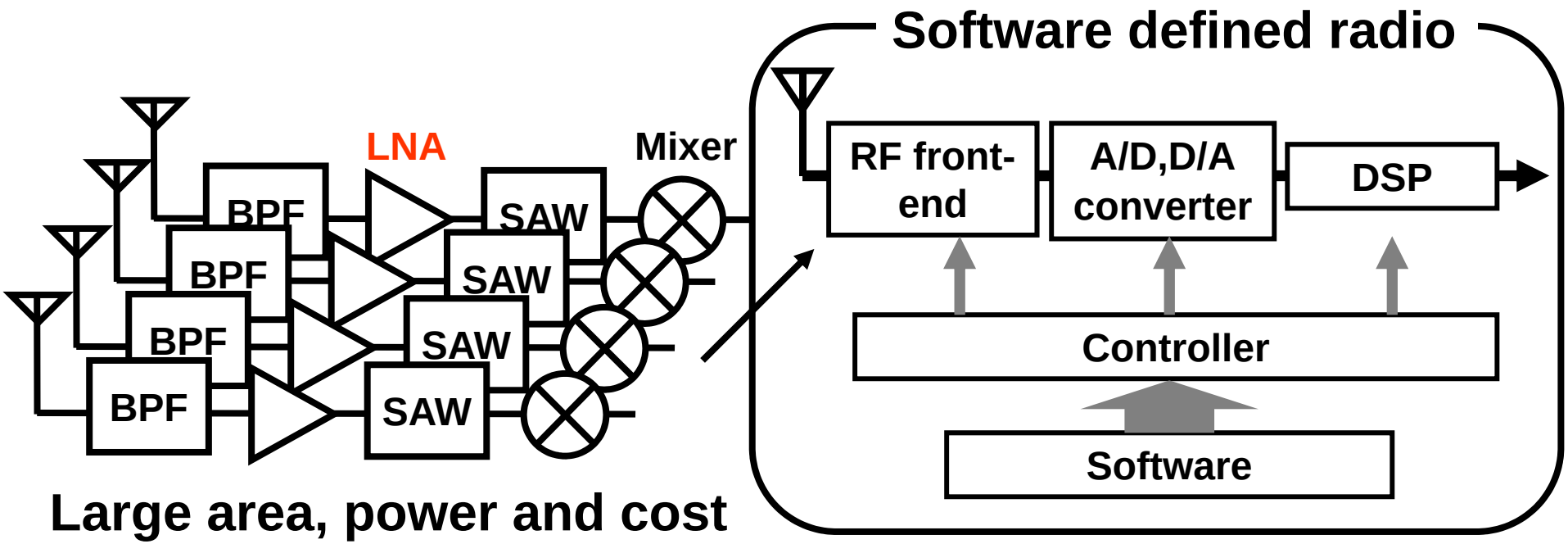
- Several RFICs are required for each wireless communication standard.
- To improve this situation, SDR is proposed.



# Requirements for SAW-less receiver



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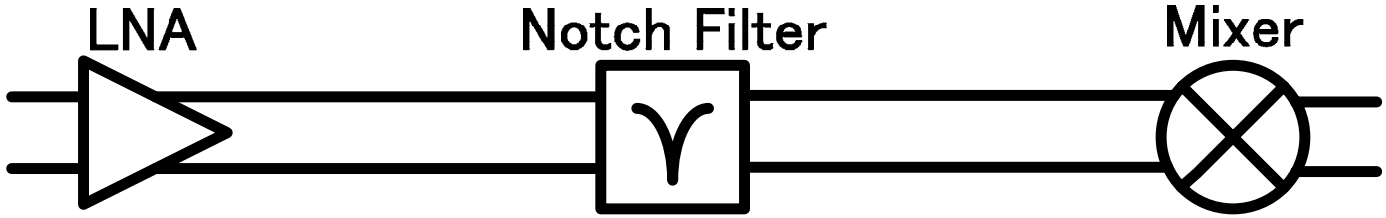
- Assuming that on chip notch filter is used instead of SAW filters.
- When Tx leak=-30dBm and CW blocker=-60dBm, requirements for components are calculated as follows.




$G_{LNA}$ =15dB
$IIP3_{LNA}$=-6dBm
$NF_{LNA}$=2.2dB

$G_{FilterTx}$=-20dB
$G_{FilterRx}$=0dB
$IIP3_{filter}$=10.5dBm

$G_{Mixer}$ =10dB
$IIP3_{Mixer}$=0.5dBm
$IIP2_{Mixer}$=60dBm

NF=3dB

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# Topology of LNAs



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- **Resistive feedback LNA**
  - **High gain, low noise**
  - **Large power**
- **Common-gate LNA**
  - **High linearity, low power**
  - **Lower gain, higher noise than resistive feedback LNA**

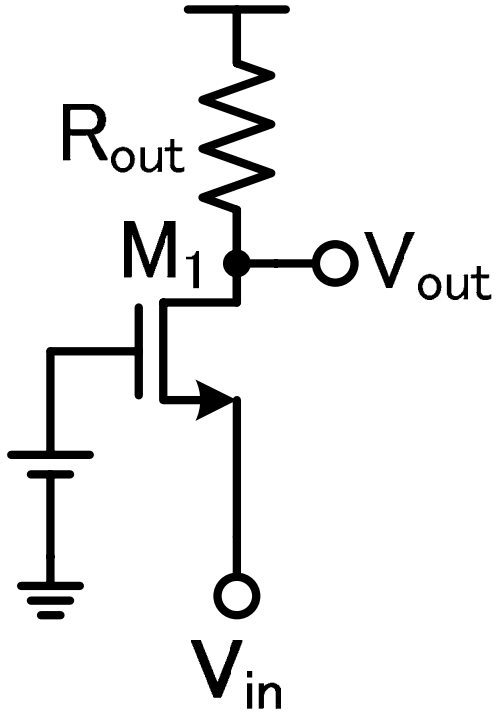
**Common-gate topology is employed.**

# Fundamental common-gate LNA





- $g_m$ of the common-gate transistor is fixed due to the input impedance matching.
- NF cannot be improved due to fixed $g_m$.




$$Z_{\text{in}} = \frac{1}{g_{\text{m}}} = R_{\text{S}}$$

$$F = 1 + \gamma + \frac{4R_{\text{S}}}{R_{\text{out}}} = 2.8\text{dB}$$

# Capacitive-Cross-Couple LNA



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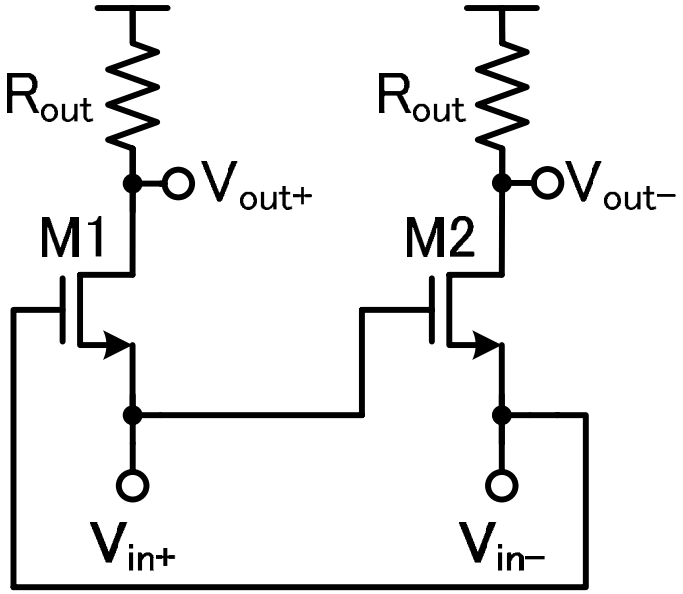
- **This topology achieves a lower noise factor than that of fundamental one.**
- **However, $g_m$ and noise of common-gate transistor are still fixed.**




$$Z_{\text{in}} = \frac{1}{2g_{\text{m}}} = R_{\text{S}}$$

$$F = 1 + \frac{\gamma}{2} + \frac{4Rs}{R_{\text{out}}} = 1.93\text{dB}$$

[1] W. Zhuo, et al. ESSCIRC, 2000.

# Proposed topology



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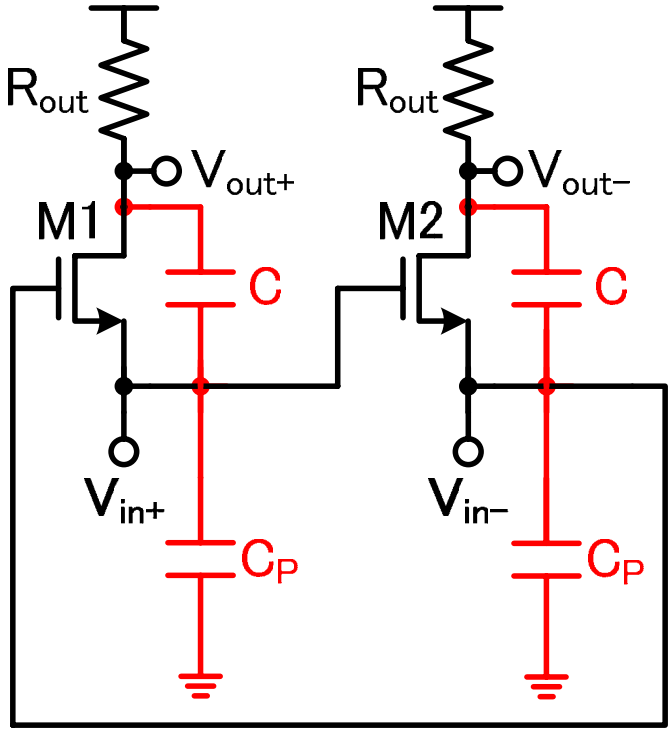
- The proposed LNA employs capacitive-cross-couple technique and **capacitive feedback**.
- $g_m$ can be enlarged, NF can be improved.




$$\mathrm{Re}(Z_{\mathrm{in}}) = \frac{1+\omega^2 C^2 R_{\mathrm{out}}^2}{2g_{\mathrm{m}}} = R_{\mathrm{S}}$$

$$F = 1 + \frac{\gamma}{2 + \dfrac{\omega^2 C^2 R_{\mathrm{S}}^2}{\left(1+\omega^2 C^2 R_{\mathrm{out}}^2\right)}} + \frac{R_{\mathrm{S}}\left(2+\omega^2 C^2 R_{\mathrm{out}}^2\right)^2 + \omega^2 C^2 R_{\mathrm{S}}\left(R_{\mathrm{S}}+R_{\mathrm{out}}\right)^2}{R_{\mathrm{out}}\left(\left(1+\omega^2 C^2 R_{\mathrm{out}}^2\right)^2 + \omega^2 C^2 R_{\mathrm{S}}^2\right)}$$

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# Noise calculation



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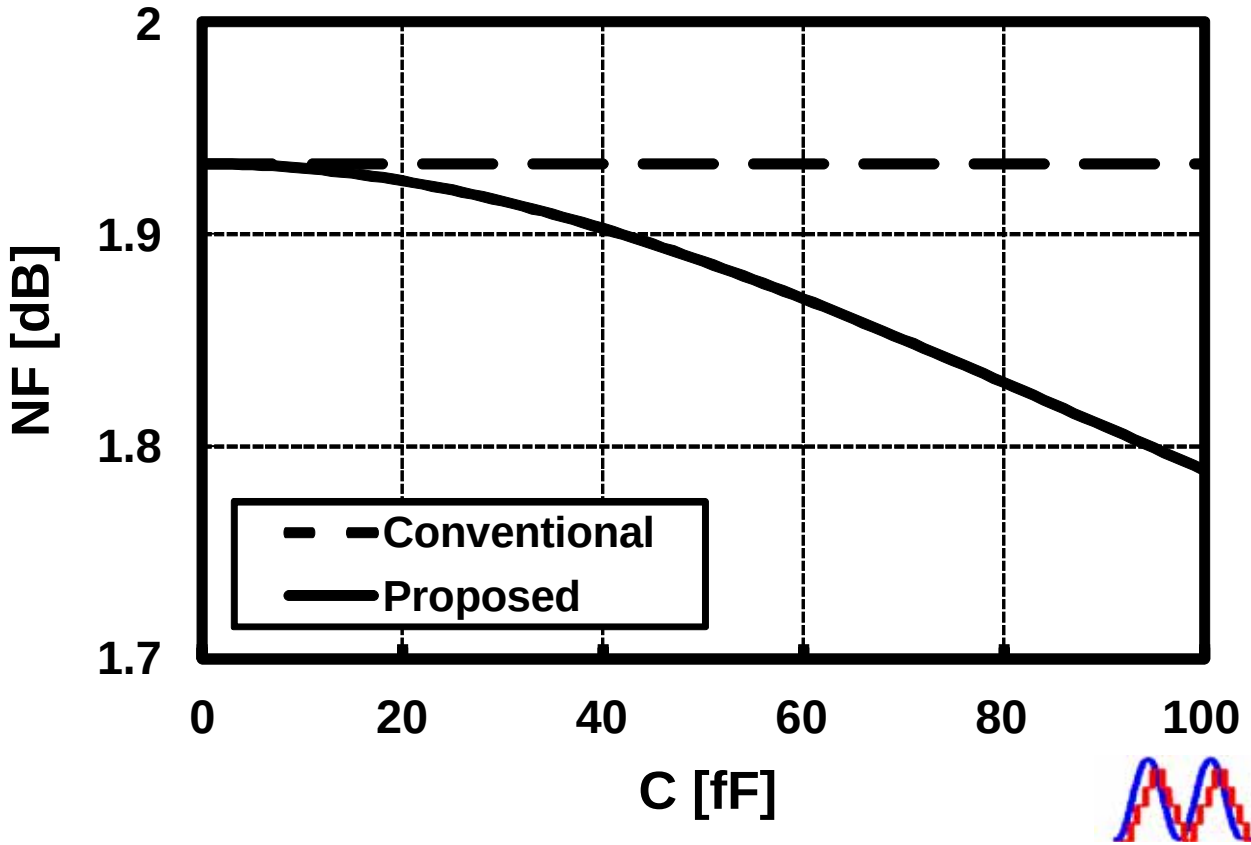
- **Calculated NFs of CCC LNA and capacitive feedback LNA are compared.**
- **The larger C is, the lower NF is.**

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# Voltage gain



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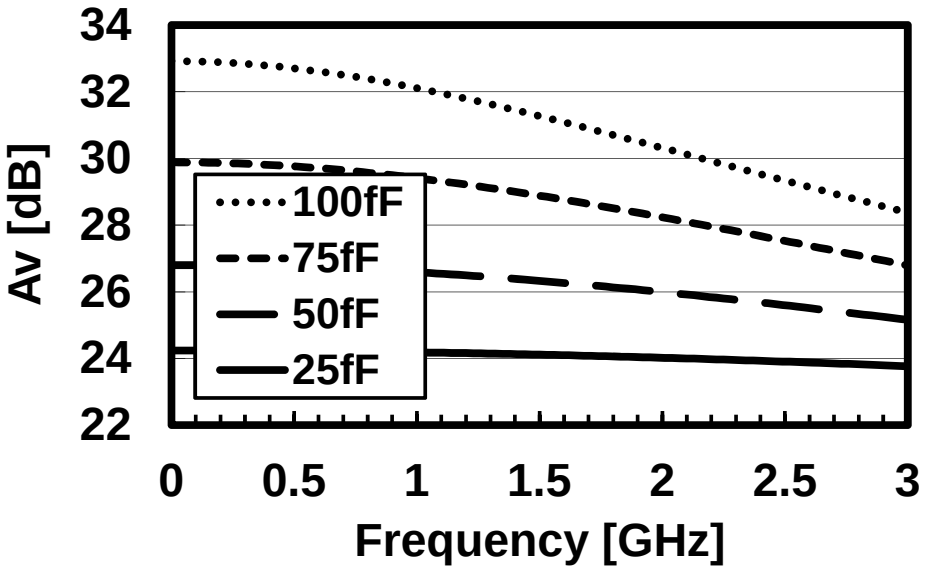
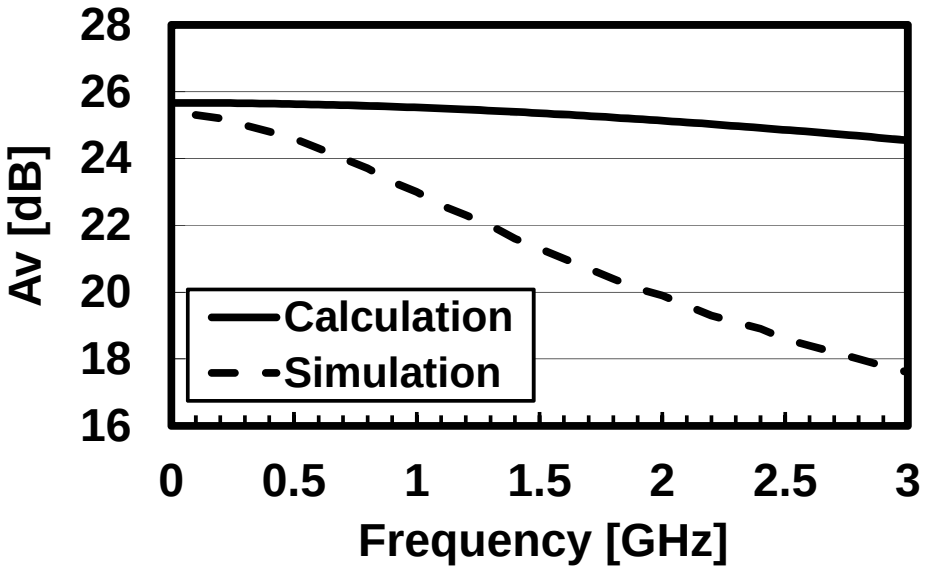
- **The larger C is, the larger but less flatness of voltage gain is.**
- **Simulated result is less flat than calculated one.**



# LNA schematic including buffer



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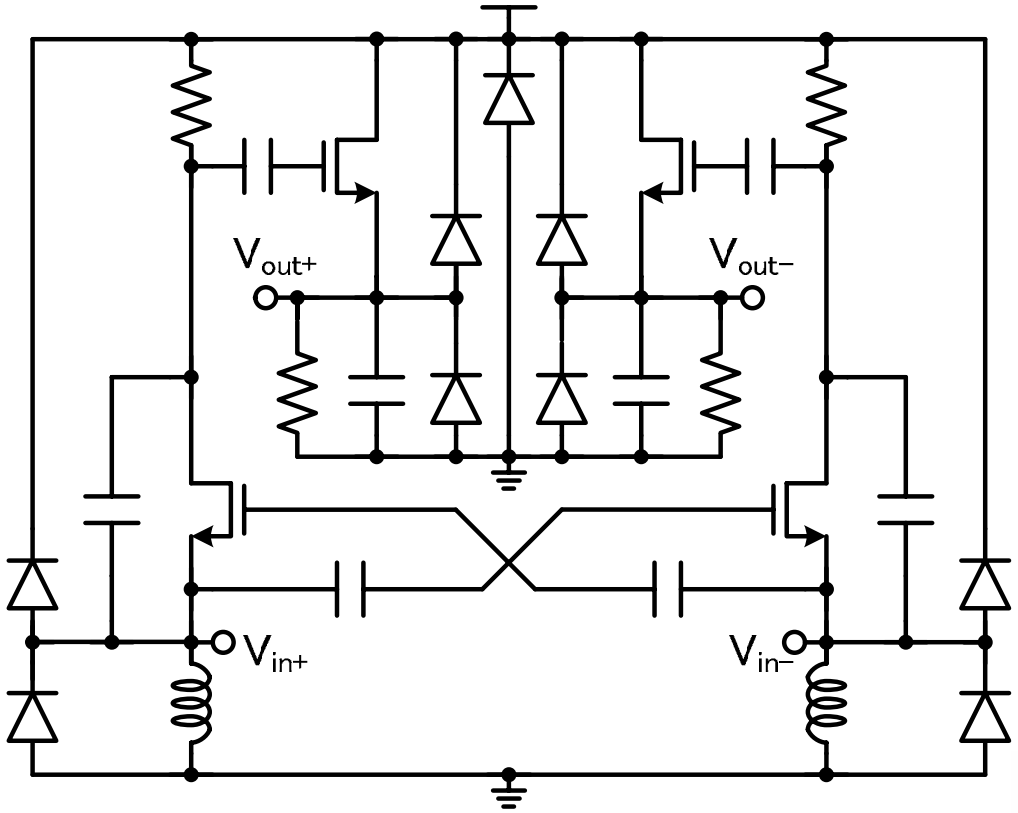
- External chip inductors are used.
- $C_P$ is implemented by ESD diode.
- The source follower buffer is connected

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# Chip and PCB photo



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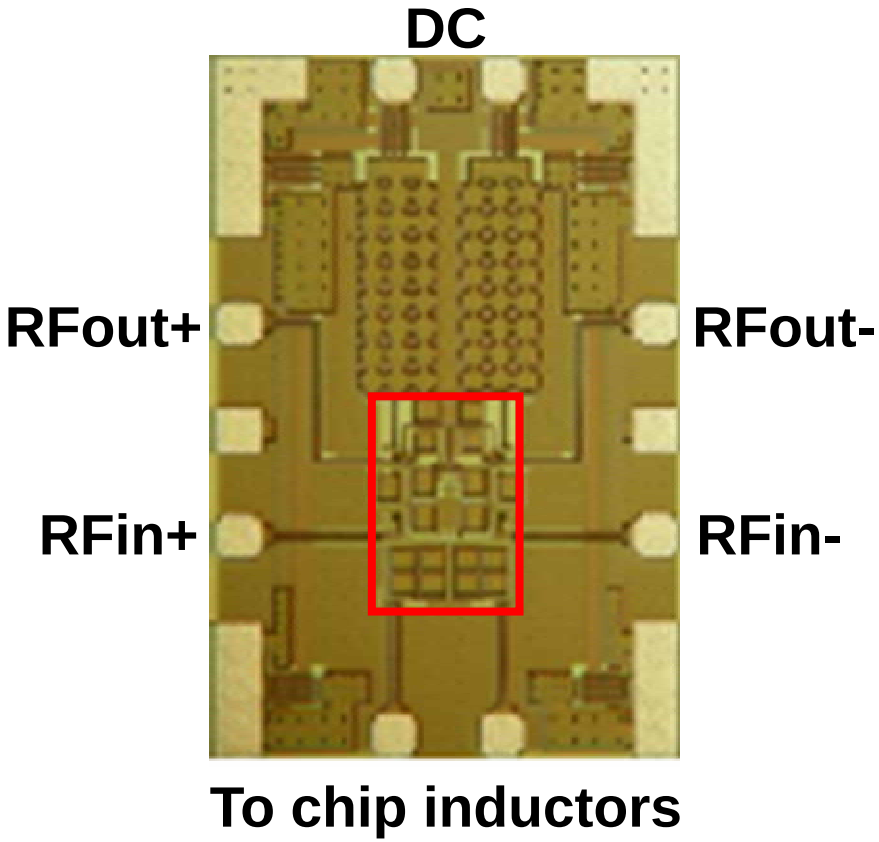
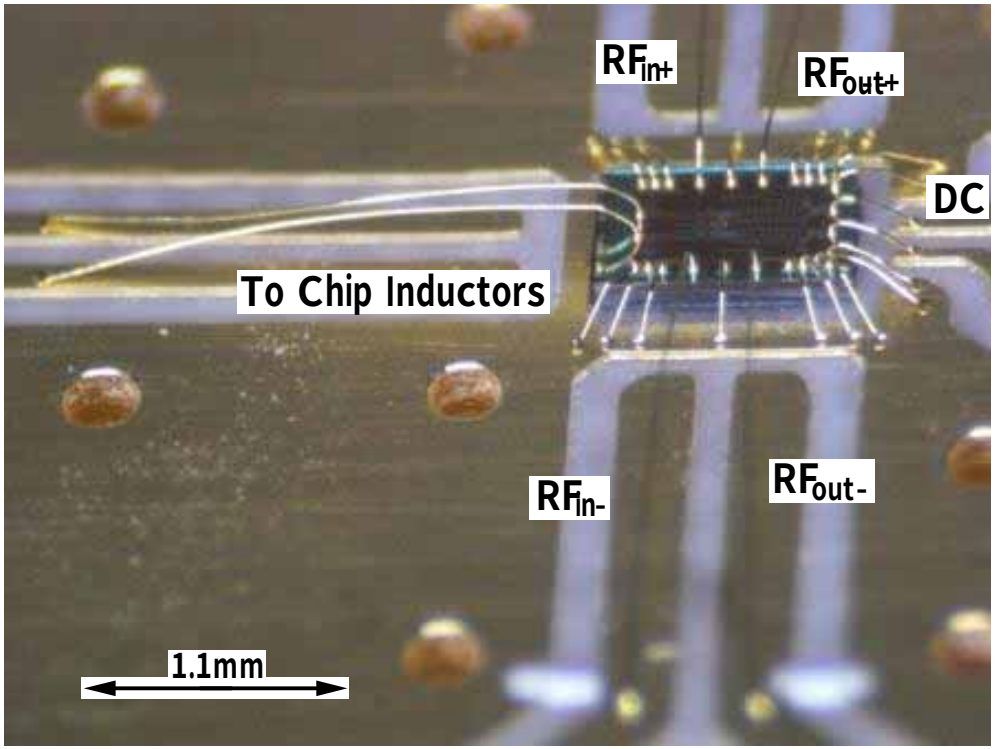
- **Nodes of photographs below correspond to each other.**
- **Core size is 0.066mm²**

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# Measured S parameters



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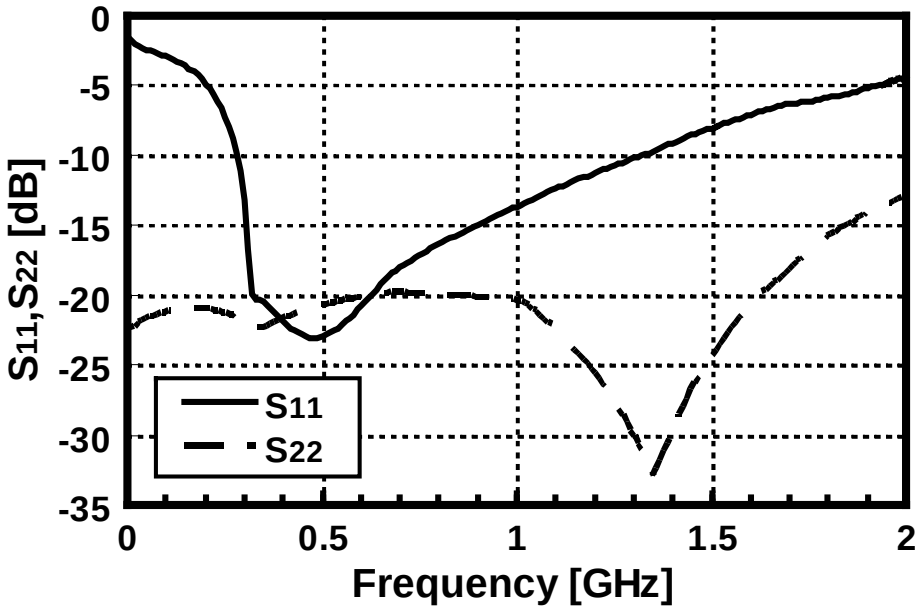
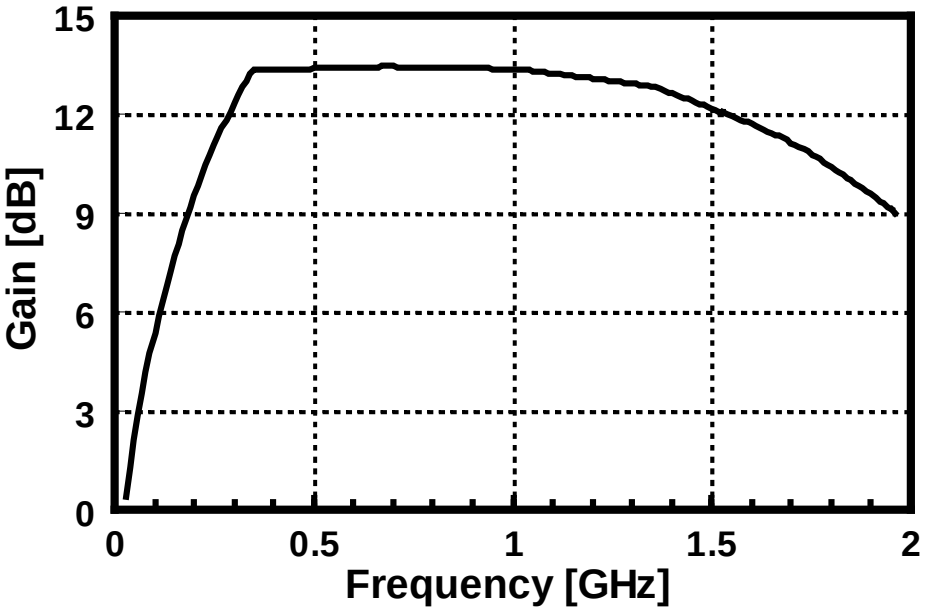
- $S_{11}$ < -5dB and $S_{22}$ < -10dB @ 0.8-1.8GHz
- Maximum power gain is 13.4dB.
- These are calculated from 4-port S-para.

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# Measured NF



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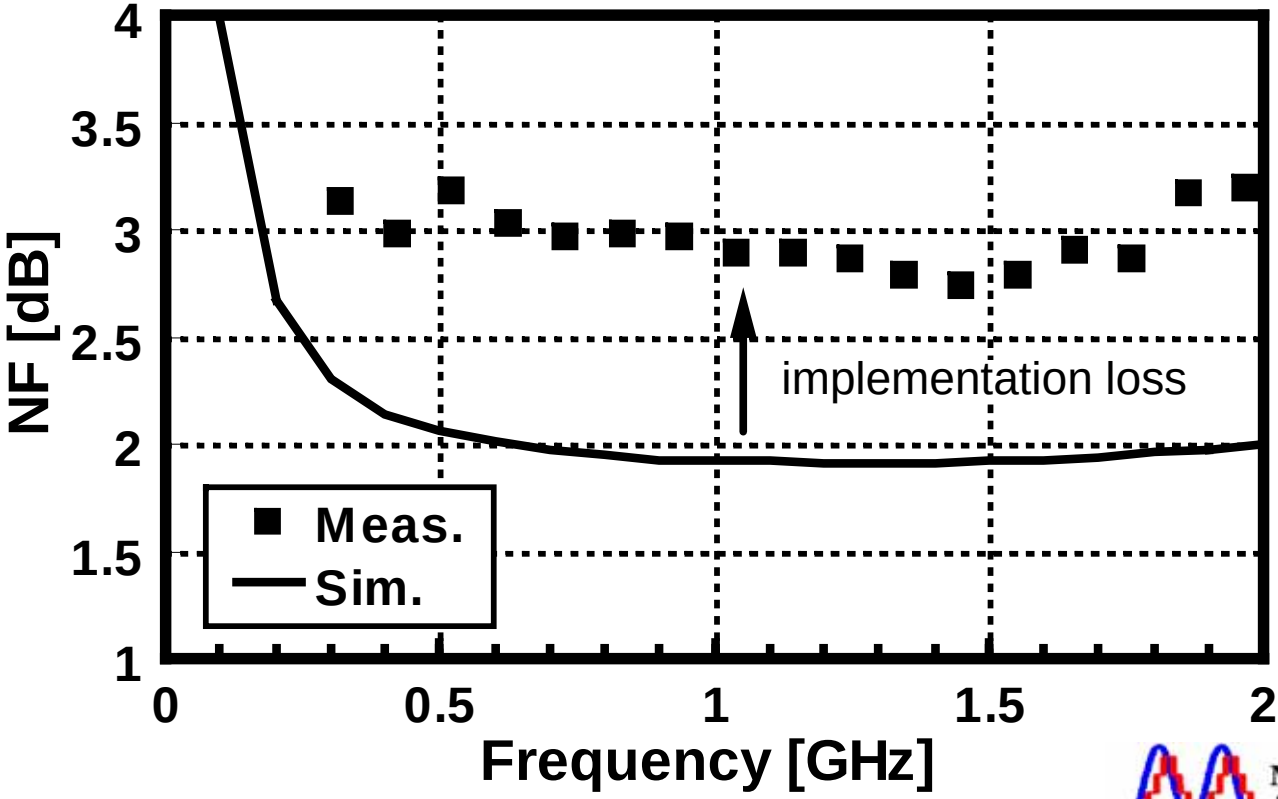
- **Measured NF is 2.7dB.**
- **This result is much higher than simulated one.**

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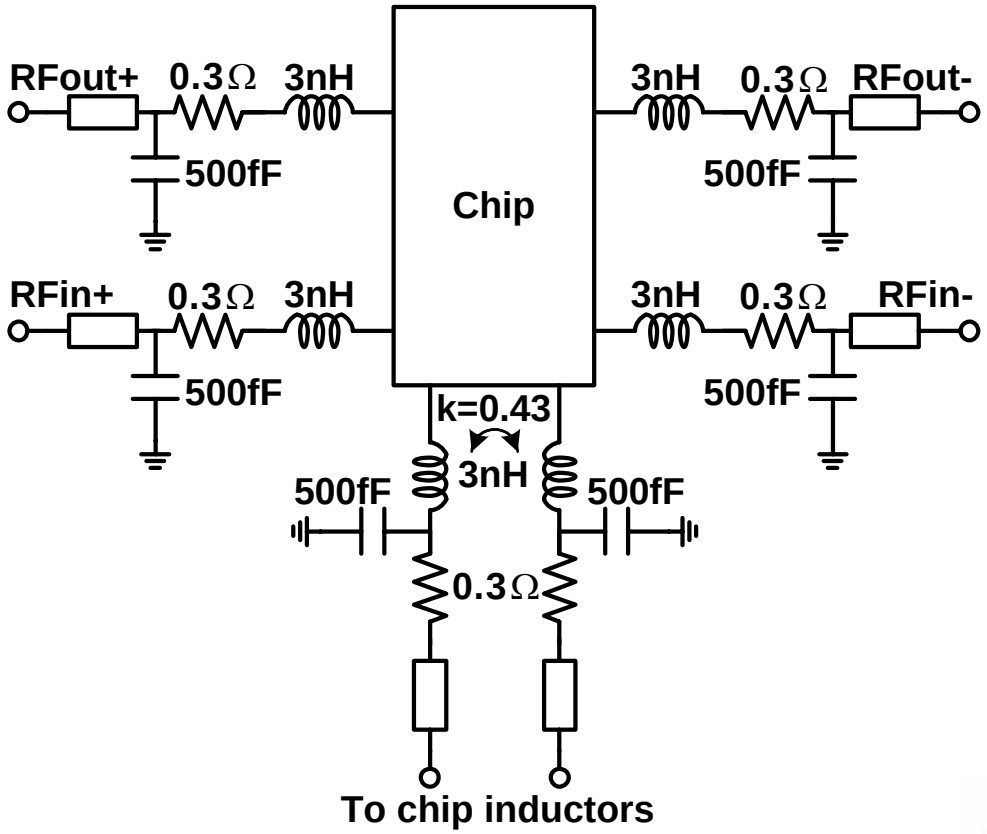
# Parasitic elements of wire and TL





- **Transmission line of PCB and parasitic of bonding wire model is made.**
- **Inductor coupling is also considered.**



# NF Comparison



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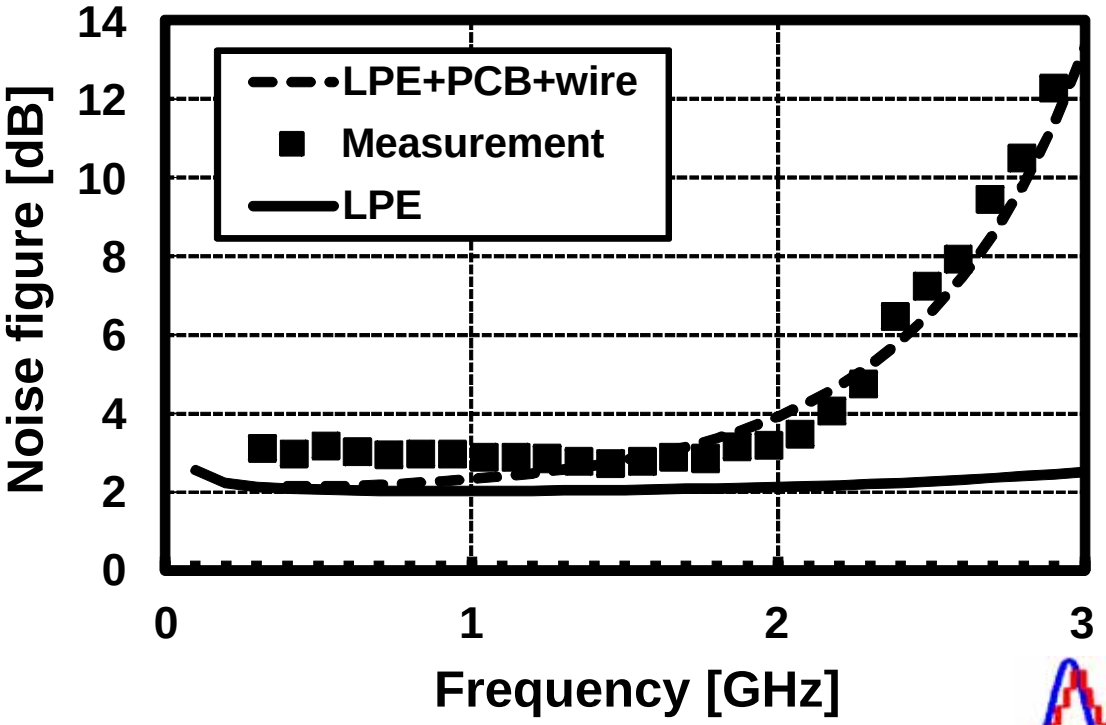
- **Measured and simulated with parasitic model NFs are compared.**
- **Simulation result using parasitic model is similar to the measured result.**



# Performance evaluation



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- **Simulation results achieve targets and NF is lower than 2dB.**
- **Measured results can be improved in consideration with the parasitics.**

| | Goal | This work | [2] |
|---|---|---|---|
| Freq. [GHz] | 0.8-2.6 | 0.8-1.8 | 0.3-0.92 |
| Gain [dB] | 15 | 13.4 | 21 |
| NF [dB] | 2.2 | 2.7 | 2 |
| IIP3 [dBm] | -6 | -7 | -3.2 |
| $P_{dc}$ [mW] | - | 6.5 | 3.6 |

[2]S.Woo, et al. ISSCC 2009

# Conclusion



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- **The wideband low noise amplifier with capacitive feedback is proposed.**
- **The capacitive feedback adds more flexibility in $g_m$ and NF can be theoretically improved.**
- **Measured and simulated NFs are much different from each other.**
- **That can be improved in consideration with the parasitic components.**

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# Thank you for your attention!