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Parallel Amplifiers Technique for LNA Design

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Abstract

A new design method for low noise amplifier (LNA) based on using parallel amplifiers to improve the linearity and output power is proposed in this paper. Noise parameters including minimum noise figure and optimum noise impedance and R_n (sensitivity coefficient) of this topology are calculated. The effect of parallel path to overall noise figure(NF) and input matching is also considered. Electro magnetic (EM) simulation result for the designed 10-12 GHz LNA with the 0.1- μm pseudomorphic GaAs HEMT model is reported to support proposed theories.

Analysis

Noise model of two parallel paths of IDCS amplifiers is shown in Fig. 1. Through the calculation of the transfer function of noise sources, noise parameters can be obtained.

$$NF_{\min} = 1 + \frac{2\gamma R_g C_{gs}^2 \omega^2}{g_m} - 2\gamma C_{gs} M \omega^2 + \frac{4\gamma C_{gs}^2 \omega^2}{g_m} \sqrt{\frac{R_g^2}{4} + \frac{M^2 g_m^2}{4C_{gs}^2} + \frac{g_m R_g}{4C_{gs}^2 \omega^2}} - M \frac{g_m R_g}{2C_{gs}}$$

$$Z_{s,opt} = \sqrt{\frac{R_g^2}{4} + \frac{M^2 g_m^2}{4C_{gs}^2} + \frac{g_m R_g}{4C_{gs}^2 \omega^2}} - M \frac{g_m R_g}{2C_{gs}} + j \frac{1}{2} \left(\frac{1}{C_{gs} \omega^2} - L_s + M \right) \omega$$

$$R_{n-p} \Big|_{M=0} = \frac{1}{2} R_{n-s} = R_g + \frac{\gamma}{g_m} (1 - L_s C_{gs} \omega^2)^2$$

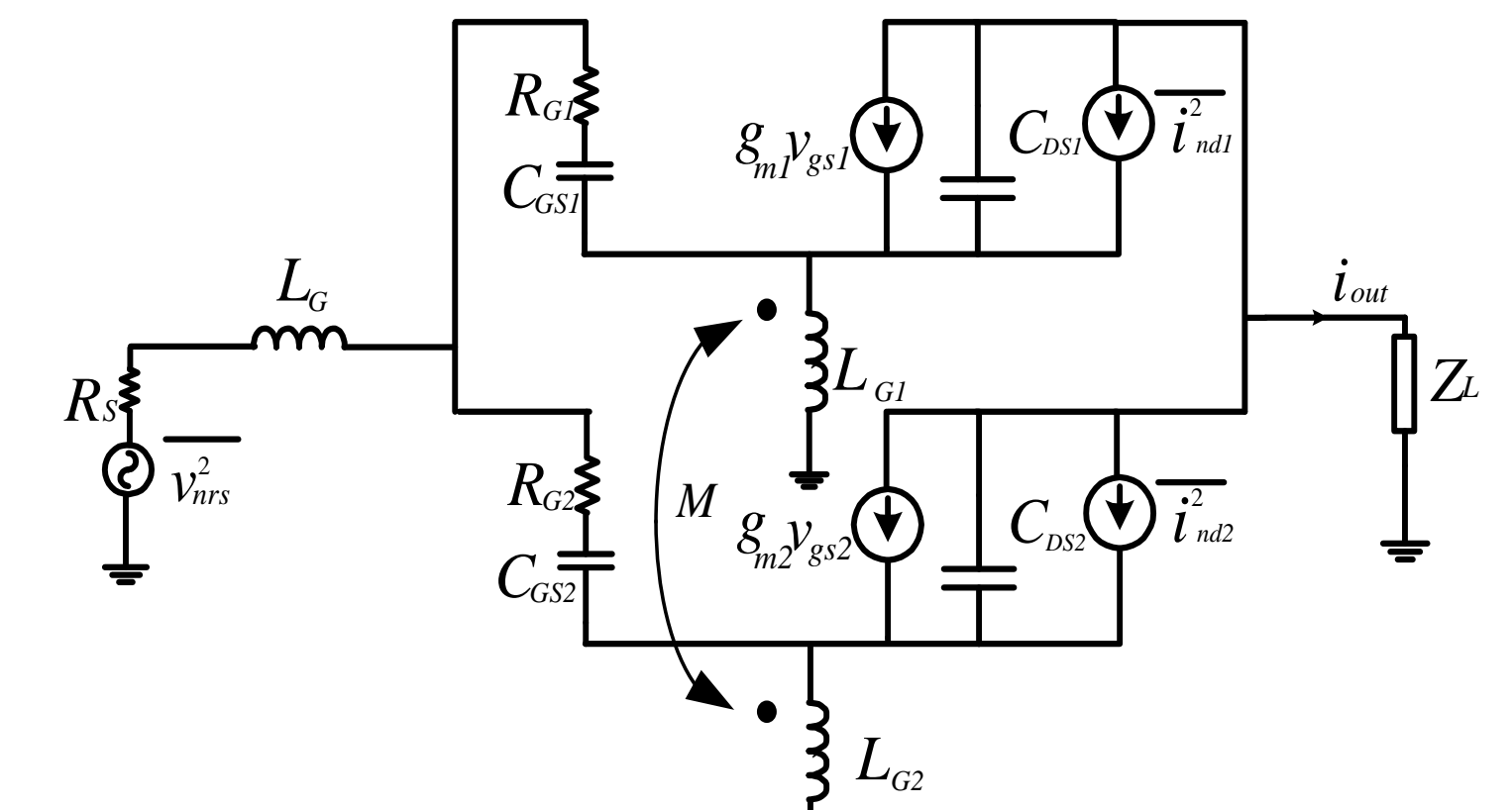


Fig1. Parallel amplifiers noise model

Parallel amplifier technique is known for linearity enhanced behavior

Theoretical calculations show this method can also be practical for desensitized LNAs

Low sensitivity causes this method to be considered as a wideband LNA topology

Results

Two different LNA are designed with bandwidth of 2 GHz for input and output matching better than -10 dB and 8 dB gain with the 0.1- μm pseudomorphic GaAs HEMT model. First LNA is a single path amplifier and second one is a parallel amplifier with two similar paths.

Results shows that :

- ✓ S11 and S22 of parallel amplifier are better than single path LNA.
- ✓ It also represents that R_n of parallel amplifier is less than single path and contrary to what we expected it causes NF of this amplifier to be lower.
- ✓ Parallel LNA topology can improve NF because of a second order factor. R_n minimization causes amplifier to have less sensitivity to source impedance and decrease LNA's dependency to input matching circuit.
- ✓ The output power versus input power behavior of both amplifiers shows that p-1dB of parallel amplifier is 3-dB better than single path LNA.

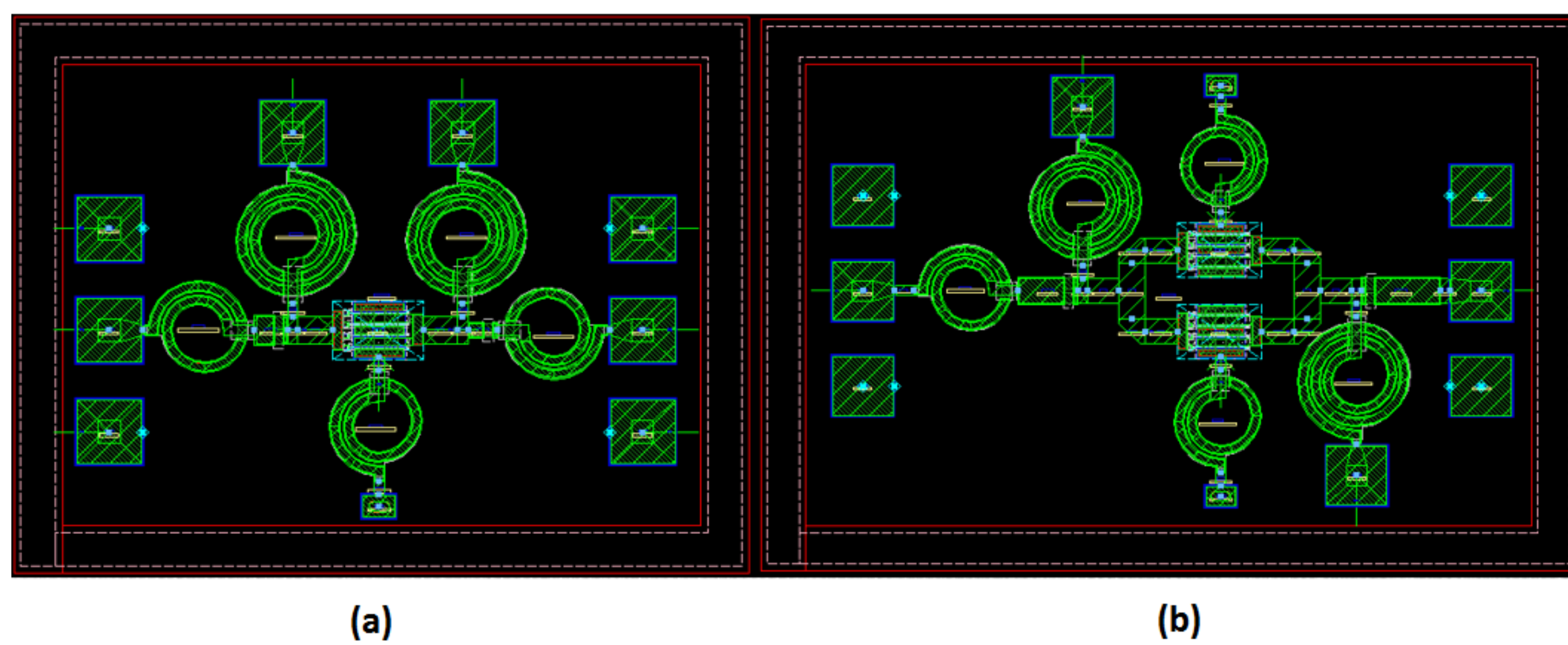


Fig2. Layout micrograph of LNAs (a) Single stage LNA (b) Parallel LNA

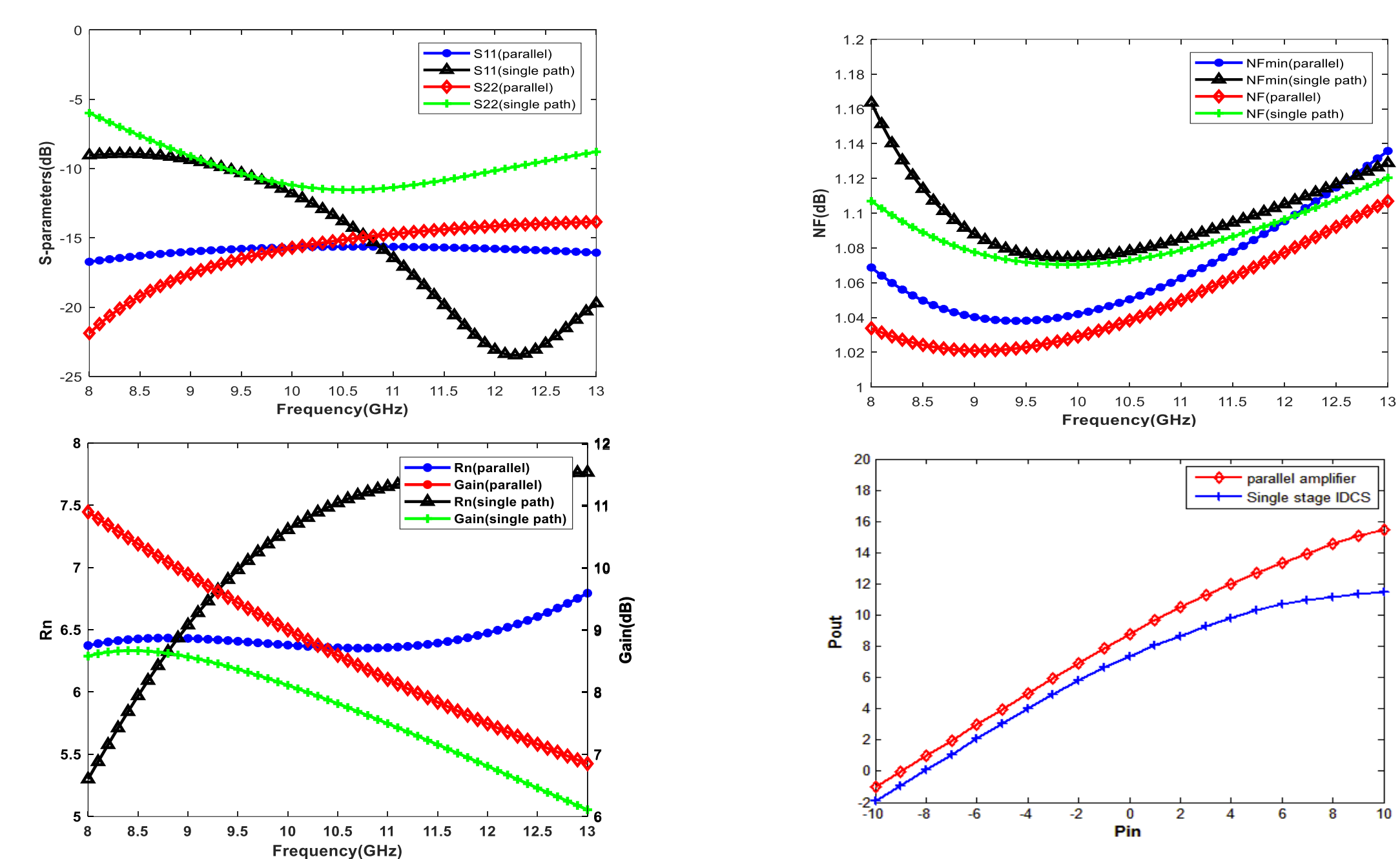


Fig3. S-parameter, Gain, R_n , NF and P1-dB Result of designed LNAs

Conclusions

- The parallel LNA exhibits the gain of 11 dB at 8 GHz with 3-dB gain bandwidth of 8-11.5 GHz, with input and output impedance matching better than -14 dB
- This topology can be considered as wideband topology with low sensitivity to source impedance and high P1-dB.
- Simulation results shows N_{fmin} almost remains the same.
- On contrary to what we expected of NF to increase due to input divider's loss it decreases because of reduction in amplifiers sensitivity to input impedance.

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