A 3.88-dB NF 60-GHz CMOS UWB LNA with 14.1-mW DC Power Consumption

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In transceiver design, LNA is a critical block, which receives signals from antenna over the whole band of interest and then amplifies them with a good signal-to-noise ratio (SNR) property. The basic requirements of an LNA include good input impedance matching (S_{11}) and reverse isolation (S_{12}), high forward gain (S_{21}), low NF and high power linearity (or phase linearity) over the whole band of interest, and low power consumption (P_D). Recently, several excellent 60-GHz-band CMOS LNAs have been reported [1]-[3]. However, the overall performances of these LNAs are not satisfactory. In the current work, in order to demonstrate that low power dissipation (< 15 mW), high S_{21} (> 10 dB), low NF (< 4 dB) and excellent phase linearity (i.e. group delay variation smaller than ±15 ps) can be achieved simultaneously for a 60 GHz LNA by using a relatively cost-effective 90 nm CMOS technology, we report a low-power, high gain and low NF 60 GHz LNA with excellent phase linearity using a standard 1P9M 90 nm CMOS technology provided by a commercial foundry.

The 60 GHz LNA was designed and implemented in a 90 nm CMOS process. The interconnection lines and the inductors were implemented with the 3.4-μm-thick topmost metal to minimize the resistive loss. The cut-off frequency (f_T) and maximum oscillation frequency (f_{max}) of the input transistor M_1 are 95.6 GHz and 136.2 GHz, respectively. The good f_T and f_{max} performances of the transistor indicate that it is possible to apply this CMOS process on the implementation of a high-performance 60-GHz LNA. To achieve sufficient forward gain and reverse isolation, the LNA was composed of a CS stage followed by a cascode stage and a CS stage. To maximize the 3 dB bandwidth of S_{21}, the output of each stage was equivalently loaded with a low-Q RLC parallel resonant circuit. Over the 60 GHz band of interest, the resonant frequency of the output of the first and third stage is close to the lower corner frequency, while that of the second stage is close to the higher corner frequency. Based on the methodology in [4], simultaneous input impedance and noise matching over the 60 GHz band of interest were achieved by appropriately selecting the values of TL_1~TL_7 as well as the size and bias of the input transistor M_1, i.e. C_{gs1} and g_{m1}. In this work, the input transistor has gate-length of 0.1 μm, gate-width-per-finger of 3 μm and finger-number of 13. The extracted C_{gs1} and g_{m1} are 32.4 fF and 23 mS, respectively. As a result, the LNA exhibited high and flat S_{21}, small group delay variation and excellent NF at the same time.

The chip area of the LNA is only 0.591×0.741 mm^2 excluding the test pads. On-wafer S-parameters and NF measurements were performed by Agilent E8361A network analyzer and Agilent N8975A noise figure analyzer, respectively. The LNA was biased at the condition of V_{d1} = 1.2 V, V_{d2} = 1.5 V, V_{d3} = 1.2 V, V_g = 0.56 V, I_{d1} = 3.6 mA, I_{d2} = 3.4 mA and I_{d3} = 3.9 mA. That is, the power consumption of the LNA is 14.1 mW. The LNA achieves S_{11} better than −10 dB for frequencies 55.1~59.5 GHz, S_{22} better than −10 dB for frequencies 55.1~59.4 GHz, and group delay variation smaller than ±13.25 ps for frequencies 50.4~63 GHz, an excellent phase linearity result for a 60 GHz CMOS UWB LNA. Additionally, the LNA achieves high and flat S_{21} of 9.9±1.5 dB and low S_{12} of –42.6 ~ –59.8 dB for frequencies 50.4~62.9 GHz. That is, the corresponding 3-dB bandwidth is 12.5 GHz. Furthermore, the LNA achieves minimum noise figure (NF) of 3.88 dB at 55.5 GHz and NF of 4.73±0.85 dB for frequencies 50~63.5 GHz, one of the best NF results ever reported for a 60 GHz CMOS LNA. Furthermore, it has been shown that stability factor μ or μ' >1 is necessary and sufficient for a circuit to be unconditionally stable. The measured result shows the LNA was unconditionally stable for frequencies 0-67 GHz.

A summary of the implemented CMOS LNA, and recently reported state-of-the-art 60-GHz-band CMOS LNAs has also done. Compared with other work, our LNA exhibits not only low power consumption but one of the lowest NFs and highest FOMs. The state-of-the-art results of the proposed LNA indicate that it is very suitable for 60 GHz UWB systems.

References

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