RF MOSFET의 바이어스 의존성을 포함하는 채널 열잡음 모델링

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Abstract

The noise behavior of a short channel MOSFET is significantly different from a long channel device. To get an accurate model for the short channel MOSFET, we use the bias dependent gamma (γ) for the channel thermal noise model. MOSFET modeling for the gate length of 0.18 ㎛ and 0.5 ㎛ demonstrate the effectiveness of the bias dependent γ concept.

I . Introduction

The sub-micron becomes very popular for CMOS technologies RF circuits due to high transit frequencies and low noise figures. Despite the improved noise performance of scaled MOSFET's, the noise generated within the device is significant and still play a major role in overall noise performance of circuits. Therefore, an accurate noise modeling is necessary to predict the noise behavior of the transistors. However, the noise behavior of the short channel is quite different from long channel device due to the various secondary effects such as short channel effect, channel length modulation, and etc. Noise model of the short channel device can be improved by properly treating the channel thermal noise, which is the dominant noise source. Several noise models have been proposed for the improvement [1],[2],[3],[4]. In this paper, we have carried the channel thermal noise model using bias dependent γ concept. We have measured the noise parameter at each bias from the measured noise data. Using the data, we get the noise model of the bias dependent factor (γ).

II. Noise modeling with bias dependent γ

Fig. 1 shows the small signal equivalent circuit model with noise sources. The thermal noise sources of MOSFET's are the channel thermal noise with channel conductance and thermal noise of the source, drain, gate, and substrate resistances. In this paper, the induced gate noise not included because the model for low frequency application performed under 3 GHz.

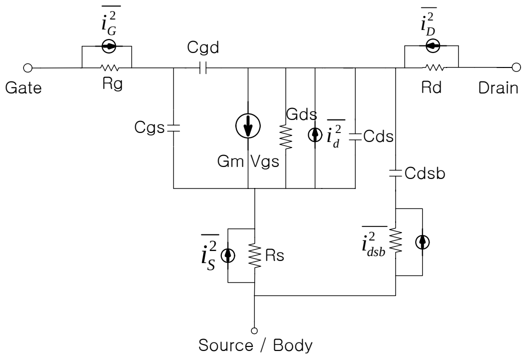


Fig. 1. Small signal equivalent circuit model with noise sources.

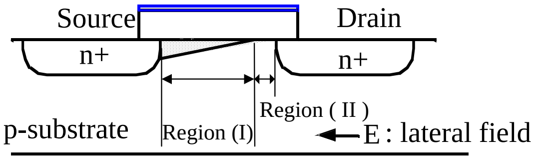


Fig. 2. Channel in region (I) and region (Ⅱ).

The modeled devices are n-type MOSFET's with gate width of 200 ㎛ (2.5 ㎛ 80 fingers) and gate lengths of 0.18 ㎛ and 0.5 ㎛, fabricated by 0.18 ㎛ CMOS technology at Magnachip Semiconductor Ltd. For reliable noise measurements with moderate impedance levels, we use the devices with the large gate width of 200 ㎛. And we model the devices with different gate lengths to compare the channel thermal noise with the different sizes. The small signal parameters are determined by fitting the model parameters to the measured S-parameters and noise data at each bias point. The thermal noises of resistances are directly calculated using the well-known formula 4kTR. The channel thermal noise current ($\overline{i_d^2}$) can be obtained from channel conductance (G_{ch}). Under the a quasi-static assumption, channel conductance (G_{ch}) has two components. As the shown a Fig. 2, one is the static conductance (G_{st}) with region (I) and another is the excess diffusion conductance (G_{ed}) with region (Ⅱ) [1], [6].

$$G_{st} = \frac{I_d}{\int dV} = \begin{cases} I_d / V_{dsat} & \text{in saturation} \\ I_d / V_{ds} & \text{in triode} \end{cases} \qquad (1)$$

V_{dsat} is the saturation drain voltage. G_{st} is gradual channel conductance of the region (I) and G_{ed} is given by [6].

$$G_{ed} = \frac{\eta k T \mu_{eff} C_{ox} W}{qL} \qquad (2)$$

η is a technology-dependent parameter with a typical value of 1. Therefore, the channel conductance is given by

$$G_{ch} = G_{st} + G_{ed} \qquad (3)$$

The channel thermal noise is influenced by the channel conductance, which is bias dependent. The channel thermal noise is modeled with the equation (4).

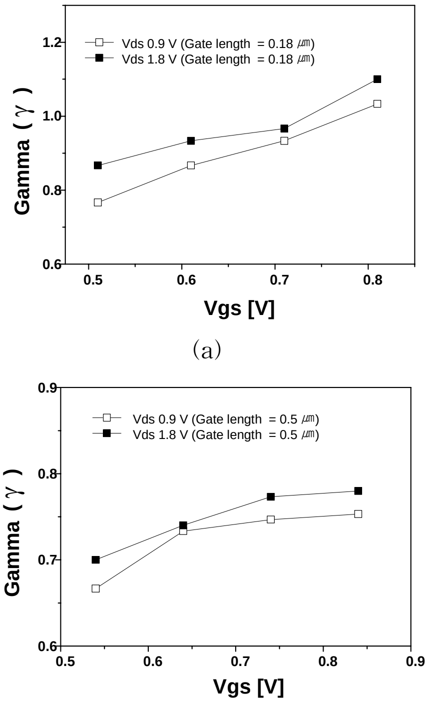
$$\frac{\overline{i_d^2}}{\Delta f} = 4kT\left(G_m + G_{ds}\right)\gamma \qquad (4)$$

The channel conductance are G_m and G_{ds}. G_{ds} is the channel output conductance. Since the noise conductance can be obtained from measured noise data and small signal model, the bias dependent γ can be extracted. Since minimum noise figure (NF_{min}) and noise resistance (R_n) and optimum source impedance (Γ_{opt}) are the most important noise parameter in circuit design, we focus on good fitting the parameters for the measured and simulated data.

Ⅲ. Comparison and Result

Fig. 3. shows extracted γ based on the small signal equivalent circuit model, which is different from the conventional γ of 2/3. The extracted γ increases with gate and drain biases. The carrier scatters due to the vertical electric field, which is increased as the gate bias is increased. As the scattering is increased, the channel thermal noise increases. When the longitudinal field becomes stronger with drain bias, stronger electric field creates the carrier heating and causes the channel length modulation [2]. Therefore, γ of the short channel device is increased. Fig. 4. shows the bias dependent noise and γ. The channel thermal noise is increased by gate and drain biases in the long

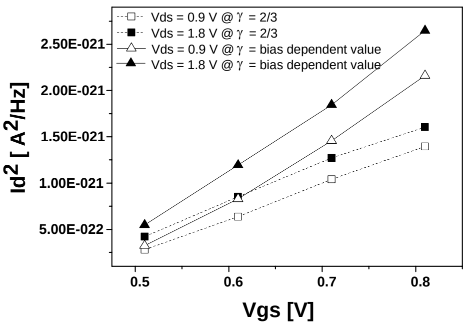
channel and short channel devices. In general, short channel has lower noise than long channel device. But γ of short channel is higher that of long channel device. Also γ increased very rapidly as V_{gs} increased. As the bias is increased, the channel thermal noise becomes a dominant source and γ is increased along with shorter channel and higher gate and drain biases. Figs. 5. and 6. show the comparisons of the measured as a function of frequencies and biases and simulated noise parameters using the bias dependent γ and conventional γ of 2/3.



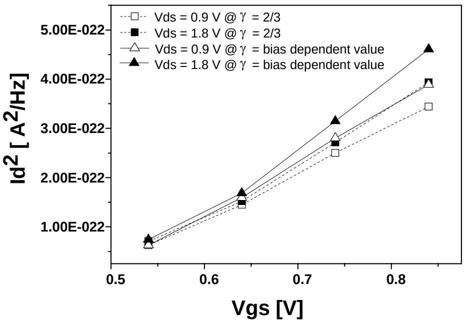
(a)

(b)

Fig. 3. Bias dependencies of γ, (a) W/L = 80 × 2.5 ㎛ / 0.18 ㎛, (b) W/L = 80 × 2.5 ㎛/ 0.5 ㎛.

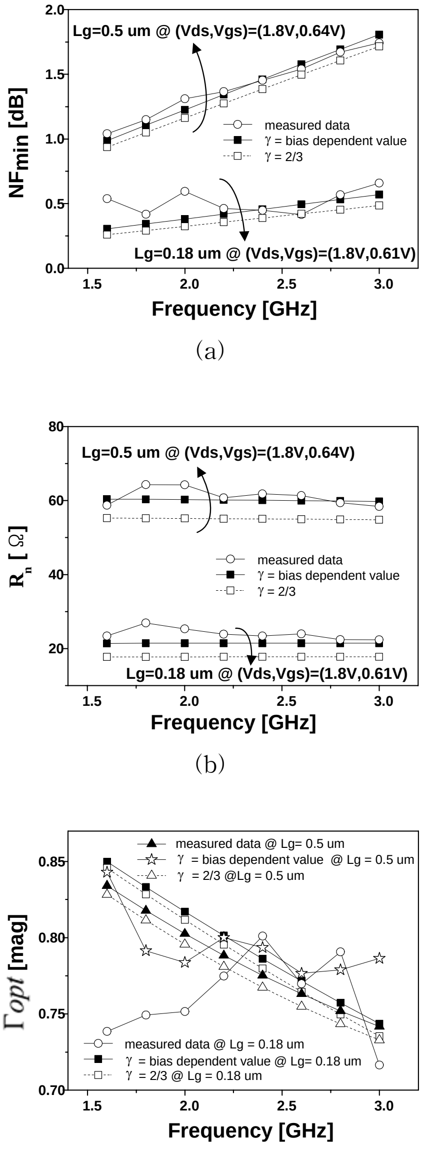


(a)



(b)

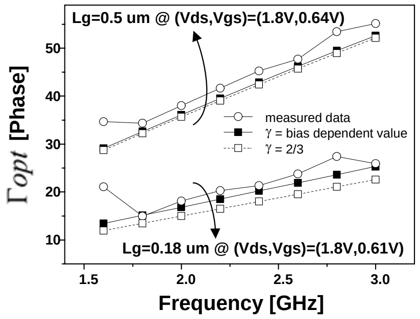
Fig. 4. Calculated channel thermal noise density (a) W/L = 80 × 2.5 ㎛ / 0.18 ㎛, (b) W/L = 80 × 2.5 ㎛ / 0.5 ㎛.



(a)

(b)

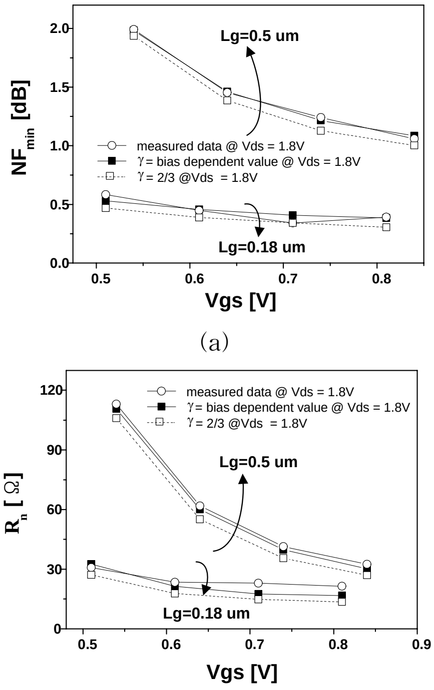
(c)



(d)

Fig. 5. Frequency dependences of noise parameters, Lg = 0.18 μm@(V_{gs}, V_{ds})=(1.8 V, 0.61 V), Lg = 0.5 μm @(V_{gs}, V_{ds}) = (1.8 V, 0.64 V), (a) NF_{min}, (b) R_n, (c) $\left|\Gamma_{opt}\right|$, (d) $\angle\Gamma_{opt}$.

Fig. 5. (c). shows that magnitude of Γ_{opt} are very small different for the conventional and bias dependent γ. In Figs. 5. (a) and 6. (a), the minimum noise figures of the long channel and short channel devices match to the measured minimum noise figure for both γ's. But in Figs. 5. (b) and 6. (b), the noise resistances of the long channel and short channel MOSFETs using the conventional γ have significant discrepancy for each frequency and bias.



(a)

(b)

Fig. 6. Bias dependences of noise parameters, (a) NFmin, (b) Rn, frequency @ 2.4 GHz.

Ⅳ. Conclusion

Noise modeling of the channel conductance for the short and long channel MOSFET's has shown an a bias dependent γ. γ is higher than the value expected in conventional long channel noise modeling. γ is influenced by the vertical field and lateral as the field is increased. The use of the bias dependent γ could model the channel thermal noise successfully.

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