A New Substrate Resistance Model of RF MOSFETs

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Ⅰ. INTRODUCTION

The substrate resistance of RF MOSFETs significantly affects the small-signal characteristics at high frequency. As a result, the contribution of the substrate resistance cannot be ignored at high frequency [1]-[3]. Although conventinal models with single or three substrate resistors have been shown to be accurate with respect to $Re[Y_{22}]$, they deviate from the measured data with other characteristic such as $Re[Y_{11}]$, $Re[Y_{12}]$. This means that they focus on the output characteristic rather than exactly describe the MOSFETs physically. The proposed model in this paper consisting of four resistors predicts well the high frequency characteristic of RF MOSFETs including $Re[Y_{11}]$, $Re[Y_{12}]$, and $Re[Y_{22}]$ up to 50 GHz. This extracting method can be achieved by two port S-parameter measurement and does not contain complex optimization process.

II. SUMMARY

Fig. 1 shows the conventional model for substrate network of the RF MOSFETs. The equivalent circuit with one substrate resistor of RF MOSFETs at V_{GS}=0 is shown in Fig. 1(a) [1], [4]. And the equivalent circuit in Fig. 1(b) is the three substrate resistors model at V_{GS}=0 [5]. The last presented model is another kind substrate model including three resistors for substrate.

The capacitances for all cases (a), (b), and (c) in Fig. 1 can be easily extracted from the obtained *Y*-parameters by using the following equations.

$$\begin{aligned} \mathrm{Im}[Y_{12}] &\cong -\omega C_{gd} \\ \mathrm{Im}[Y_{11}] &\cong \omega(C_{gd}+C_{gs}+C_{gb}) \\ \mathrm{Im}[Y_{22}] &\cong \omega(C_{gd}+C_{jd}) \end{aligned} \qquad (1)$$

The followings are about the methods to obtain resistance value for each model in Fig. 1. There are redundancies for extracting resistors in Fig. 1(a) and (b) model. For example, equation (2) is derived from Fig. 1(a). Every equation of (2) can give the value of the R_{sub}. The first equation among the three is employed to extract the value of R_{sub} for better output characteristic prediction [4].

$$\begin{aligned} \mathrm{Re}[Y_{22}] &\cong \omega^2 C_{jd}^2 R_{sub} \\ \mathrm{Re}[Y_{11}] &\cong \omega^2 C_{gb}^2 R_{sub} \\ \mathrm{Re}[Y_{12}] &\cong \omega^2 C_{gb} C_{jd} R_{sub} \end{aligned} \qquad (2)$$

The redundancy is also existed in the case of Fig. 1(b). To overcome these problems, extraction method base on four-port measurement is used in [5].

Fig. 1(c) is proposed to predict output characteristic well one up to 50 GHz. It introduces very simple method for extraction. But, it has a drawback that it does not match well with the measured $Re[Y_{11}]$ and $Re[Y_{12}]$.

The newly proposed model is presented in Fig. 2. The following equations (3) are the simplified results from Fig. 2. It can be verified that there is no redundancy among the three equations. The three resistors R_{gb}, R_{db}, and R_{bb} can be obtained by using all of the three equations.

$$\begin{aligned} \mathrm{Re}[Y_{22}] &\cong \omega^2 C_{jd}^2 (R_{db}+R_{bb}) \\ \mathrm{Re}[Y_{11}] &\cong \omega^2 C_{gb}^2 (R_{gb}+R_{bb}) \\ \mathrm{Re}[Y_{21}] &\cong \omega^2 C_{gb} C_{jd} R_{bb} \end{aligned} \qquad (3)$$

Table Ⅰ and Fig. 3 is the result of the case of odd number of fingers. Table Ⅰ shows the value of extracted parameters, and measurement and simulation results are compared for each model in Fig. 3 for Nf = 15. The result of even number of fingers (Nf = 16) are also presented in Table Ⅱ and Fig. 4.

In the case of single resistor model (dash lines), there is a significant difference between measurement and simulation for both cases of Nf = 15, 16. In the case of three resistor model (dash dot lines) [5], the output characteristic ($Re[Y_{22}]$) of the device is very well predicted. However, $Re[Y_{11}]$ and $Re[Y_{21}]$ are not matched.

The solid lines show results of the new suggested model. In terms of $Re[Y_{22}]$, this new model gives a consequence as accurately as three resistor model. In addition, there is also a good agreement with respect to $Re[Y_{11}]$ and $Re[Y_{21}]$.

ACKNOWLEDGMENT

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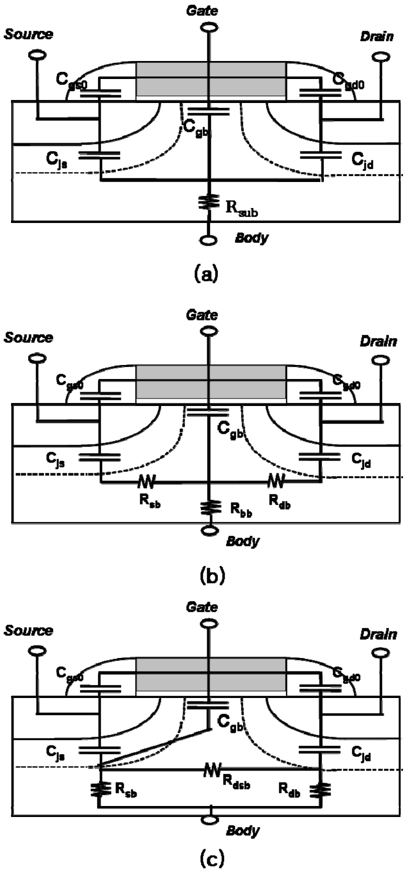

Fig.1 Equivalent Circuit for existed model with (a) one and (b) three substrate resistance components, (c) is a modified three resistor model for predicting accurately the output characteristics of MOSFETs.

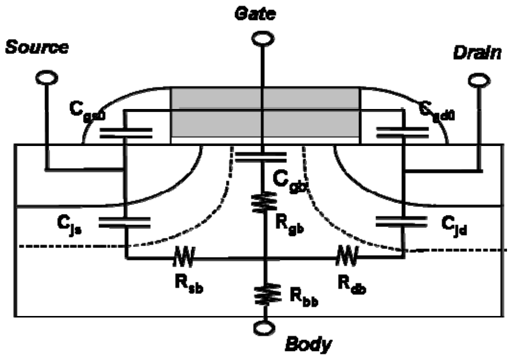

Fig. 2 The newly proposed model for substrate resistance consisting of four resistors

TABLE Ⅰ

Capacitances and resistances extracted from measurements for odd finger (nf = 15) device

Model	C_{gs0}(fF)	C_{gd0}(fF)	C_{gb}(fF)	C_{js}(fF)	C_{jd}(fF)	Resistors
Fig.1(a)	48	48	17.6	68.4	68.4	R_{sub}=109 Ω
Fig.1(c)	48	48	17.6	68.4	68.4	R_{dsb}=17 Ω, R_{sb}=216 Ω, R_{db}=216 Ω
New model	48	48	17.6	68.4	68.4	R_{bb}=102, R_{sb}, R_{db} =7, R_{gb}=175

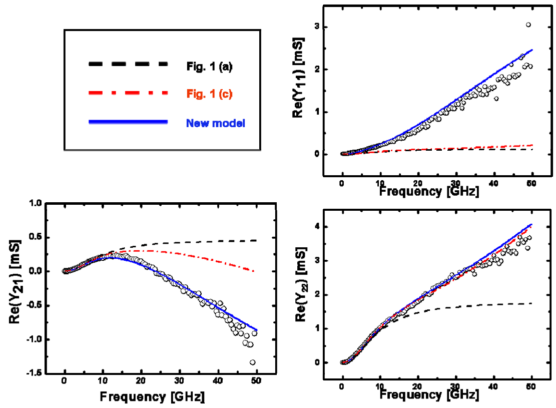

Fig. 3 Modeled and measured Y-parameters for frequencies up to 50GHz. Lines represent simulation result with obtained parameters and circles are measurement result. (Nf = 15)

TABLE Ⅱ

Capacitances and resistances extracted from measurements for even finger (nf = 16) device

Model	C_{gs0}(fF)	C_{gd0}(fF)	C_{gb}(fF)	C_{js}(fF)	C_{jd}(fF)	Resistors
Fig.1(a)	50.7	50.7	18.9	80	72.3	R_{sub}=104.8 Ω
Fig.1(c)	50.7	50.7	18.9	80	72.3	R_{dsb}=11.2 Ω, R_{sb}=101
New model	50.7	50.7	18.9	80	72.3	R_{bb}=94.6, R_{db} =10.2, R_{gb}=181.4

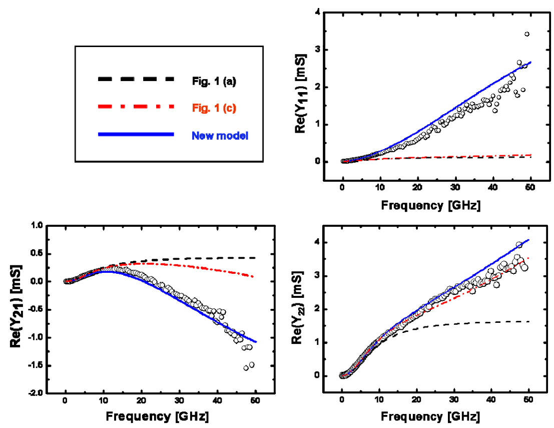

Fig. 4 Modeled and measured Y-parameters for frequencies up to 50GHz. Lines represent simulation result with obtained parameters and circles are measurement result. (Nf = 16)