Reliability Evaluation of RF Power Amplifier for Wireless Transmitter

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Abstract—A class-E RF(Radio Frequency) power amplifier for wireless application is designed using standard CMOS technology. To drive the class-E power amplifier, a class-F RF power amplifier is used and the reliability characteristics are studied with a class-E load network. The reliability characteristic is improved when a finite-DC feed inductor is used instead of an RF choke with the load. After one year of operating, when the load is an RF choke the output current and voltage of the power amplifier decrease about 17% compared to initial values. But when the load is a finite DC-feed inductor the output current and voltage decrease 9.7%. The S-parameter such as input reflection coefficient(S11) and the forward transmission scattering parameter(S21) is simulated with the stress time. In a finite DC-feed inductor the characteristics of S-parameter are changed slightly compared to an RF-choke inductor. From the simulation results, the class-E power amplifier with a finite DC-feed inductor shows superior reliability characteristics compared to power amplifier using an RF choke.

Index Terms—RF power amplifier, class-E, class-F, reliability, stress time.

I. INTRODUCTION

The main requirements for RF power amplifier used in wireless communication are low power consumption, high power efficiency and high output power. In recent, much study has focused on one-chip RF circuit design [1, 2]. Mainly GaAs (Gallium Arsenide) has been used to implement RF circuits because of high operating speed. But it is difficult to implement one-chip RF circuit using GaAs technology. CMOS technology has be a suitable candidate to implement RF circuit with the improving CMOS process technology [3, 4, 5, 6]. And deep submicron CMOS technology offers lower cost and higher integration capability than GaAs technology. However, the HC (Hot Carrier) stress and FN (Fowler-Nordheim) stress are a critical problem in deep submicron CMOS circuit. The performance of CMOS circuit can be degraded points of the transconductance characteristics, threshold voltage and mobility shift.

In this paper, a class-E RF power amplifier is designed using 0.25μm standard CMOS technology. The reliability characteristics of a class-E power amplifier report with a load network.

II. CLASS-E POWER AMPLIFIER DESIGN

Fig. 1 shows the schematic of class-E power amplifier. In the class-E power amplifier, the important issue is the input waveform by the driver stage to turn the MOS M2 on and off. Ideally, a square waveform should be applied to the M2 to reduce transition times. The best solution to generate a square wave is by using a class F power amplifier with driving circuit [7]. The class-F power amplifier is realized by the transistor M1 and LC tanks (L_{O1}, C_{O1} and L_{O3}, C_{O3}) which resonates at the first and third harmonics of the carrier frequency. The finger number of transistor M1 is 300 and the width and length are 0.25μm and 0.25μm, respectively. The class-E power amplifier consists of MOS M2 and LC tank(L_E, C_E). The finger number of transistor M2 is 400 and the width and length are 0.25μm and 0.25 μm, respectively.

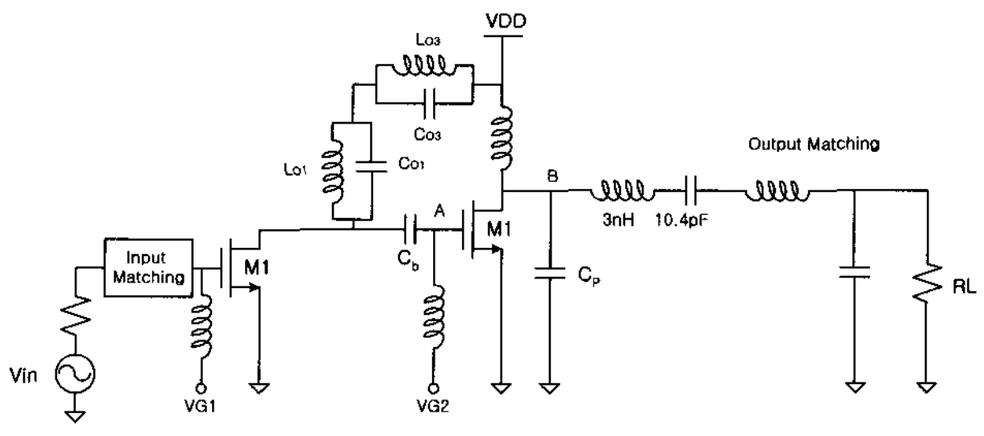

Fig.1 Schematic of class-E power amplifier

In the class-E power amplifier MOS M2 operates as a switch and this operation leads to high voltage stress because the drain voltage of the class-E power amplifier is approximately 3.6 times the supply voltage. In the class-E power amplifier the drain voltage of MOS M2 can be reduced with the load network. The drain voltage is 2.5 times the supply voltage when a finite DC-feed inductor is used instead of a RF choke inductor [8].

Fig. 2 shows the simulated gate voltage(node A) and drain voltage(node B) waveforms when the supply voltage is 1.8volts. When the RF choke, 1mH, is used as the load inductor the drain voltage of MOS M2 is about 6.5volt. However when a finite DC-feed inductor, 1nH, is used the drain voltage of MOS M2 is about 4.5volt.

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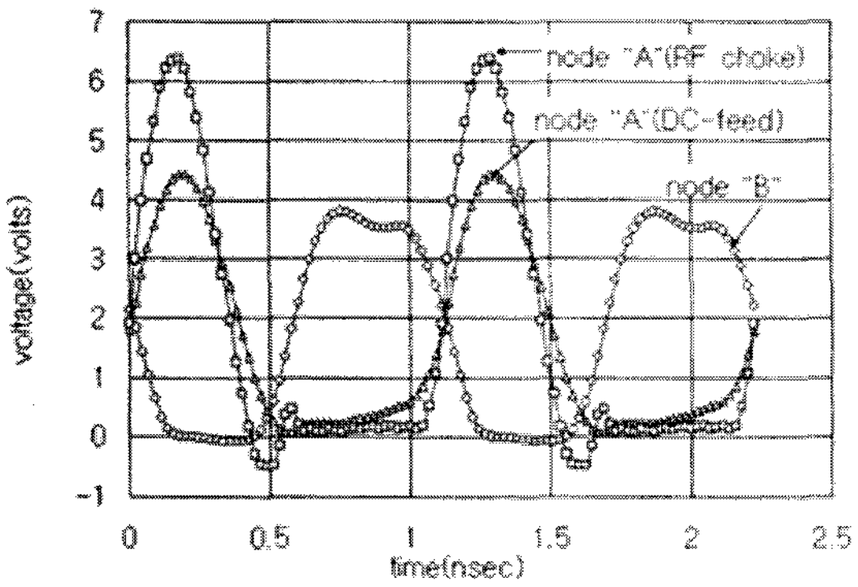


Fig. 2 Gate and drain voltages in RF power amplifier

III. CIRCUIT SIMULATION WITH STRESS TIME

The electrical characteristic of MOS M2 is degraded due to a high drain voltage with operation time. Recently, a degradation subcircuit model is described after HC stress and FN stress as a function of substrate current and operation time [9, 10]. The subcircuit model describing device characteristics changes due to HC stress and FN stress.

The stress condition is that V_{GS} is 1.8V and Isub/(W/L) is 1nA and 0.35nA, respectively. When the drain voltage, V_{DS}, is 6.5V Isub/(W/L) is 1nA and when V_{DS} is 4.5V Isub/(W/L) is 0.35nA [11]. Fig. 3 shows the drain current change of MOS M2 with the stress time. The used model is Wei-Cheng Lin's degradation subcircuit model to analysis MOS characteristics with the stress time. As shown in Fig. 3 when the substrate current, Isub/(W/L), is 1nA the drain current reduces about 49% after one year. But when the substrate current, Isub/(W/L), is 0.35nA the change of drain current is about 17%.

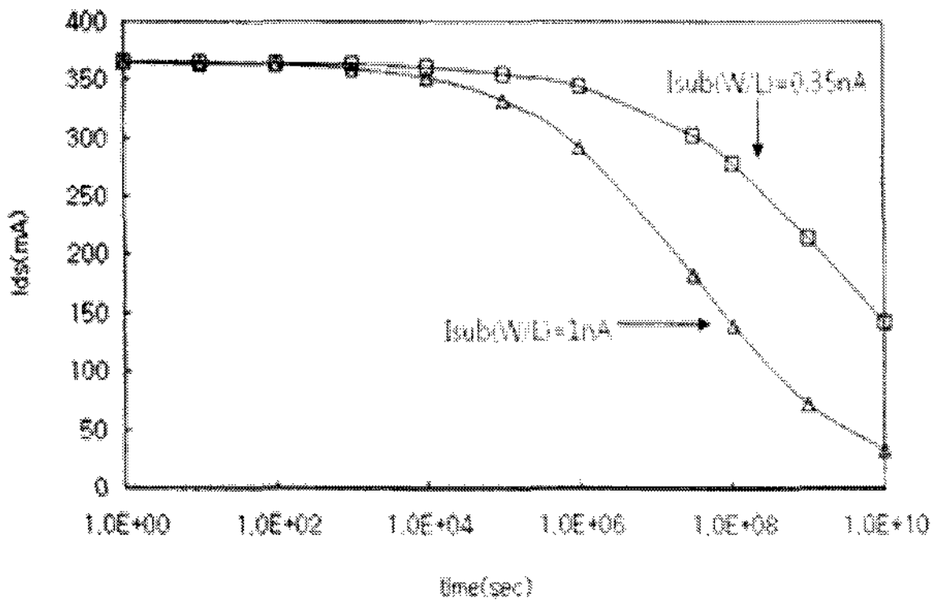
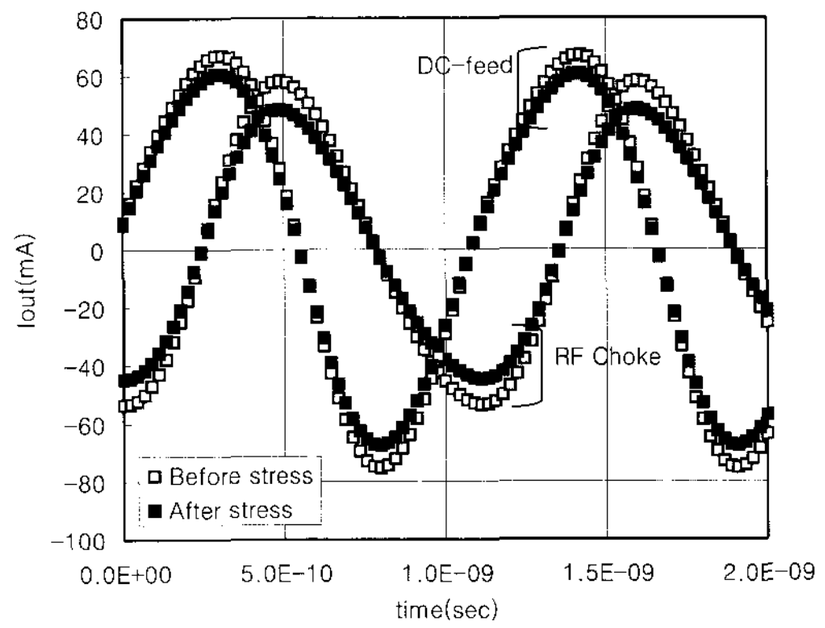
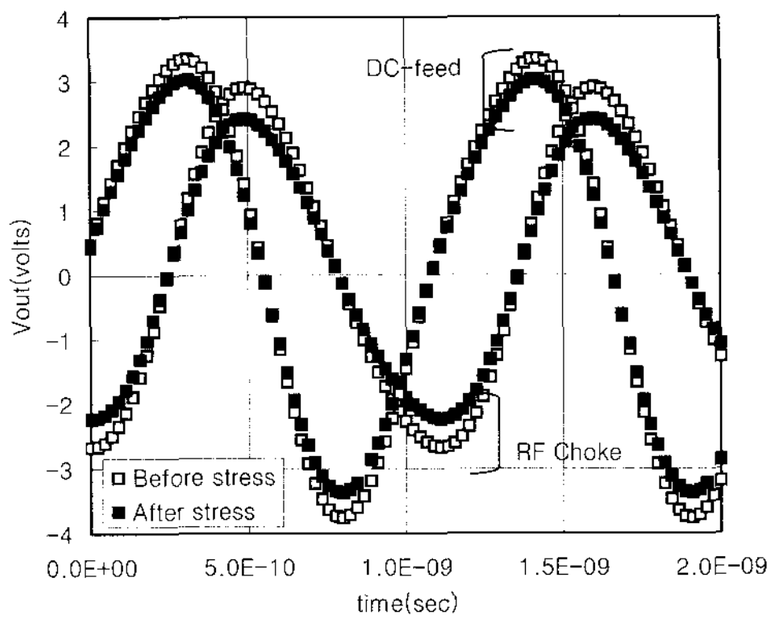


Fig. 3 Drain current change with stress time

Fig. 4 (a) and (b) show the output current (Iout) and the output voltage (Vout) waveforms before and after stress. In case of an RF choke Iout and Vout decrease about 17% compared to initial Iout and Vout. But Iout and Vout decrease only 9.7% when the load is a finite DC-feed inductor.



(a)



(b)

Fig. 4 Output current and voltage waveforms after stress time (a) Output current (b) output voltage

Fig. 5 and Fig. 6 show the effect of the stress on the input reflection coefficient (S11) and the forward transmission scattering parameter (S21). From Fig.5 and Fig.6 the S11 is changed significantly, while the S21 only decreases slightly. In an RF-choke S11 parameter is changed more significant than a finite DC-feed inductor due to high drain voltage [12]. There is no movement of the minimum S11.

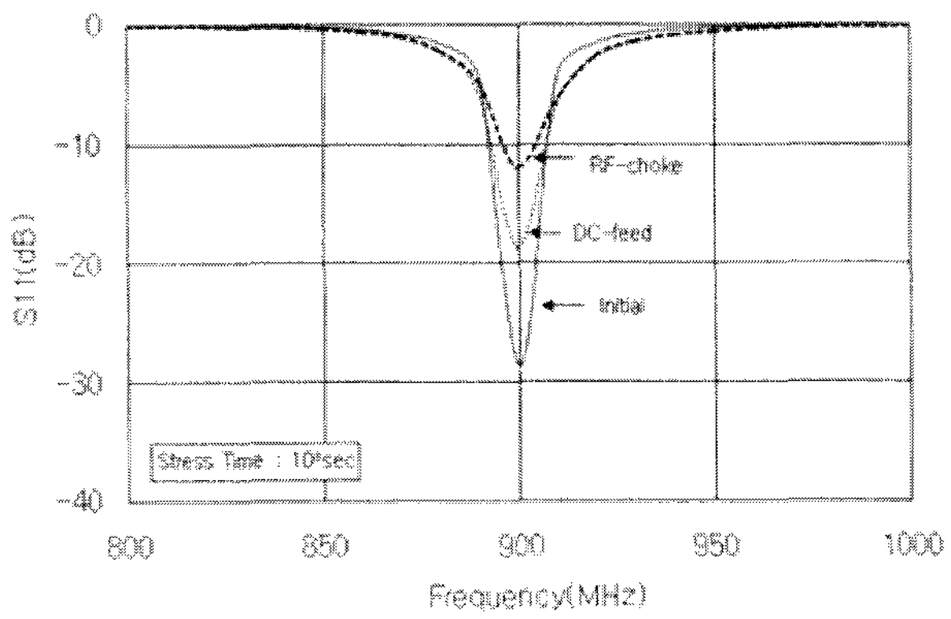


Fig. 5 S11 versus frequency before and after stress

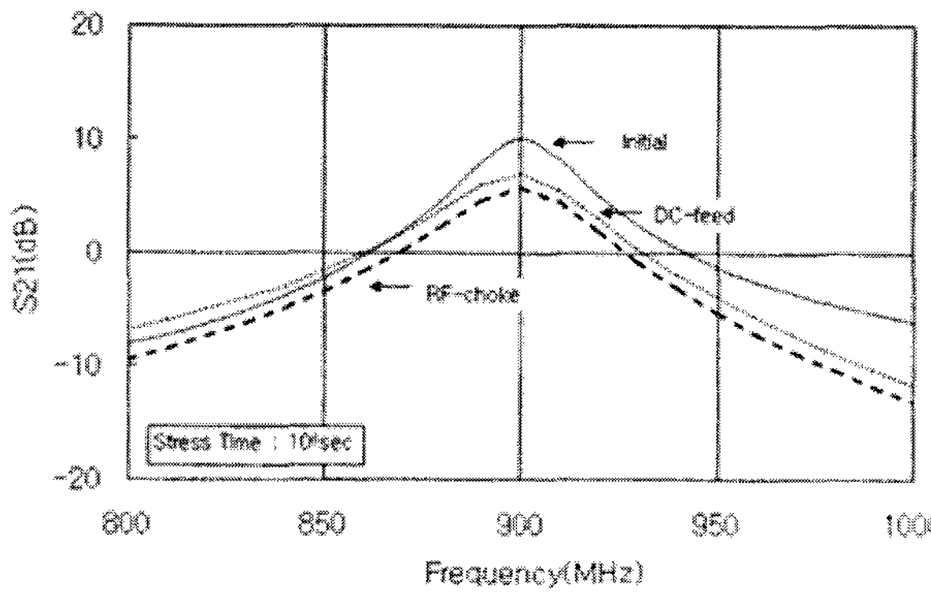


Fig. 6 S21 versus frequency before and after stress

Fig. 7 and Fig. 8 show the change of PAE and the output power with stress time. After one year, the PAE decreases about 12% in the power amplifier with an RF choke. However, the PAE decreases 6.5% in case of a finite DC-feed. The output power decreases about 28.6% in the power amplifier with an RF choke and the output power decreases 18.7% in case of a finite DC-feed.

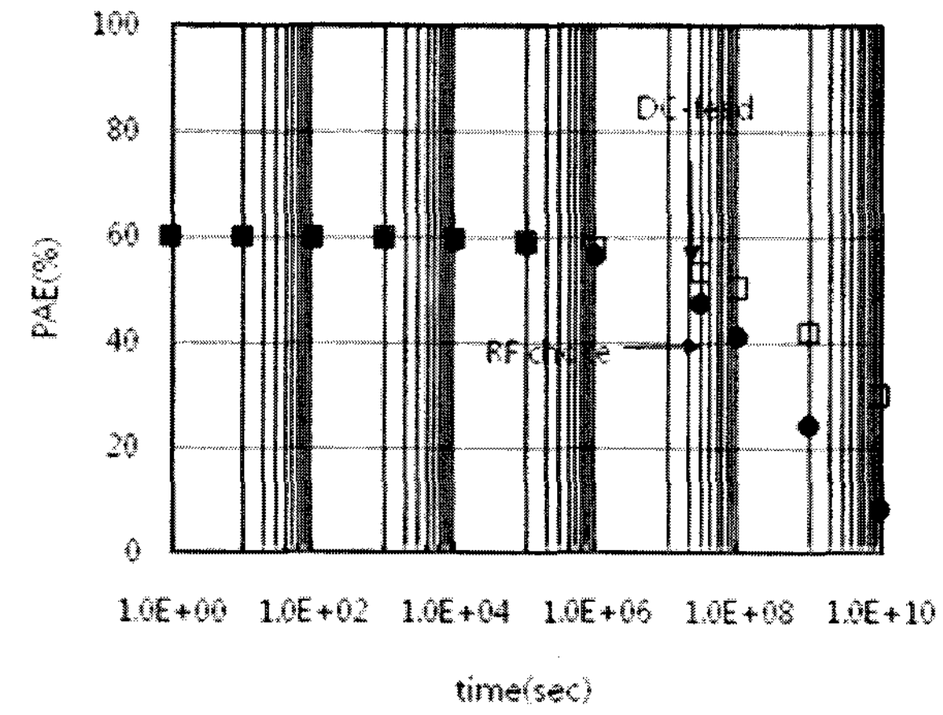


Fig. 7 PAE change with stress time

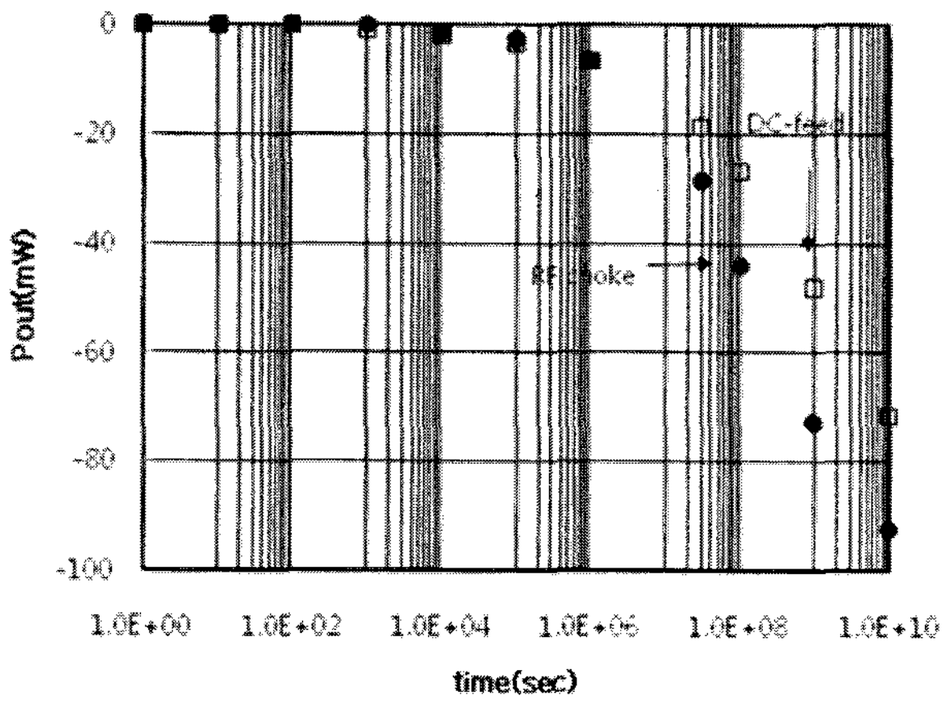


Fig. 8 Output Power change with stress time

The simulated results show the class-E power amplifier with a finite DC-feed inductor exhibits superior reliability characteristics.

IV. CONCLUSIONS

A reliability characteristic of a class-E power amplifier was studied with the load network. A class-E RF power amplifier with 1.8volts power supply is designed using 0.25μm standard CMOS technology at 900MHz. After HC stressing, the performance degradation of power amplifier using an RF choke was more serious than a finite DC-feed amplifier. Also the class-E amplifier with finite DC-feed inductance provides high efficiency and high output power compared to RF choke amplifier. The simulated results show that the class-E power amplifier with a finite DC-feed inductor has superior reliability characteristics.

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