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전차단 상태에서 동작하는 안테나 튜닝스위치의 RF 보호기술

RF protection technique of antenna tuning switch in all-off condition

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ABSTRACT

This paper, we presents a RF protection technique of antenna switch by improving the power handling capability in worst case environment mode for mobile phone applications without critical payment of circuit performances such as insertion loss, isolation and ACBV (AC breakdown voltage). By applying a additional capacitive path located in front of the antenna in cell-phone, it performs the effective reduction of input power in high voltage standing wave ratio (VSWR) condition. Under the all-path off condition which causes a high VSWR, it achieved 37.7dBm power handling level as high as 5.7dB compared to that of conventional one at 2GHz. In addition, insertion loss and isolation performances were 0.31dB and 42.72dB at 2 GHz, respectively which were almost similar to that of the conventional circuit. The proposed antenna switch was fabricated in 130nm CMOS SOI technology.

Keywords : RF protection, single-pole double throw (SPDT), VSWR(voltage standing ratio), RF switch

Ⅰ. Introduction

As the continuous improvement of 5th-generation (5G) and multiple-input multiple-output (MIMO) techniques [1-5], it faced with a challenging situation in which various frequency bands need to be implemented in a small mobile device form factor. In other words, mobile device must increase the bandwidth of existing antennas. However, at this broadband frequency, the impedance of the antenna switch is not constant and can vary significantly, resulting in very high VSWR (Voltage Standing Wave Ratio) condition. In this case, power handling capability of switch can be severely degraded because the high VSWR leads a high reflected voltage from antenna [6]. Thus, it is regarded as an essential requirement for reliable operation of RF antenna switch, antenna impedance tuning switch (ATS) and aperture tuning switch [7]. Despite this importance, there have been several previously reported papers to prevent high VSWR and degradation of power handling capacity. In this paper, we proposed a RF protection technique to improve the power handling capability in all-path off mode which cause high VSWR condition of antenna switch without critical payment of performances such as insertion loss, isolation and ACBV under the normal operation.

Ⅱ. Circuit Design of Antenna switch with RF protection technique

As depicted in Figure 1, proposed RF protection circuit (RFP) changed the effective capacitance with RF switch operation modes and have a capacitor and stacked-FETs in series. In our design, when the switch is operating normally, that is, when either of the two series paths is on, most of the RF signal power incident from the antenna is transmitted without reflection, so it becomes a low VSWR condition and the transistor of

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RFP is off. In this situation, since the RFP part is maintained with a low capacitance, the deterioration of the RF switch performances such as insertion loss, port-to-port isolation and ACBV due to the RFP can be minimized.

On the other side, when the switch is off, that is, when all of series paths is off, most of the RF signal power incident from the antenna is reflected without transmission, so it becomes a high VSWR condition and the transistor of RFP is on. Thus, RFP part have a high capacitance so that protects the switch device from the effectively large amount of input power by additional loss path. And, turn-on and off sate transistors in RFP are simply expressed by a low on-resistance (TR_{ON}) and capacitance(TR_{off}) as shown in Figure 5, respectively.

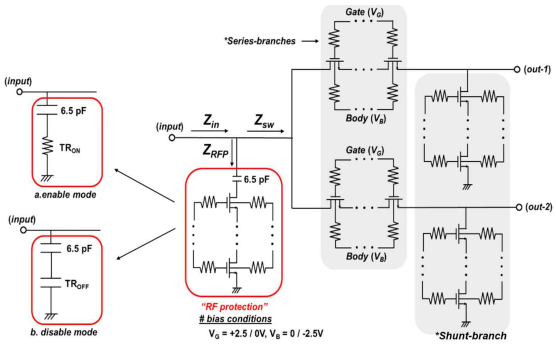

Fig. 1 SPDT scheme including the proposed RF protection circuit and equivalent circuit.

The designed SPDT switch has multi-stacked configuration, floating gate/body and negative biasing for high power handling capability. To control on and off state of the stacked transistor, the on-state transistor was applied with 2.5 V to gate and 0 V to body, respectively. And the off-state transistor used -2.5 V to gate and -2.5 V to body, respectively. To optimize the capacitance of RFP, in our design the 6.5 pF of capacitor is finally selected.

Additionary, we confirmed input impedance change with the control bias of RFP under the all-path off condition as shown in Fig 2. It can be seen that the input impedance of the circuit is significantly reduced in the RFP enabled case compared to the disabled case according to the control signal. Also, as shown in Fig. 3, when an input signal of 30dBm is incident to the antenna under the switch all-off condition, how the switch input signal is attenuated due to the RFP operation was confirmed through simulation. In the case of a conventional antenna switch, the input voltage is a peak-to-peak voltage of 28V, but when RFP is applied, it is reduced to about 12V, and the overvoltage situation is improved by more than 50%, confirming that it is suitable for circuit protection.

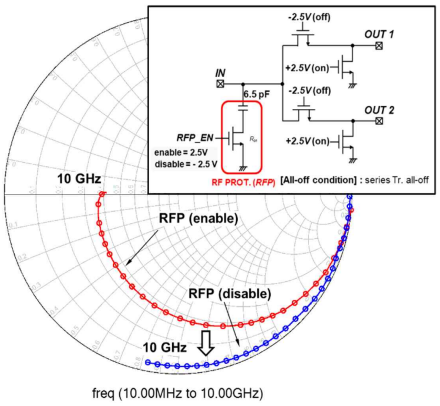

Fig. 2 Simulation results of input impedance change with RFP operation in all-path off condition.

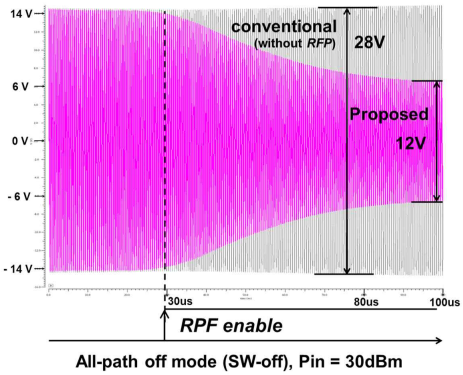

Fig. 3 Transient simulation results of input signal of antenna switches with RFP operation in all-path off mode (@ Pin=30dBm).

Ⅲ. Experimental Results

Figure 4 shows a photograph of conventional and proposed antenna switches with ESD (electrostatic discharge) block, respectively. And, to digitally control the switch operations, level shifter block was also employed. When the fundamental signal of 2GHz was incident, the power handling level of the proposed switch verified through the 3rd harmonic test was measured at 37.7dBm, which was improved by about 5.7dB compared to conventional one as depicted in Fig 5.

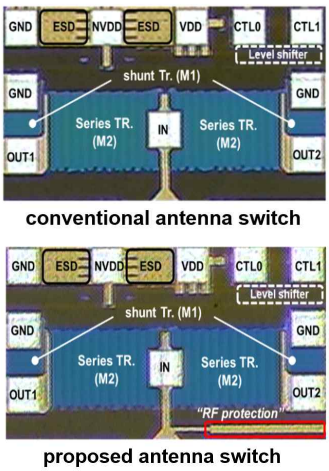

Fig. 4 Photograph of the fabricated conventional and proposed antenna switches.

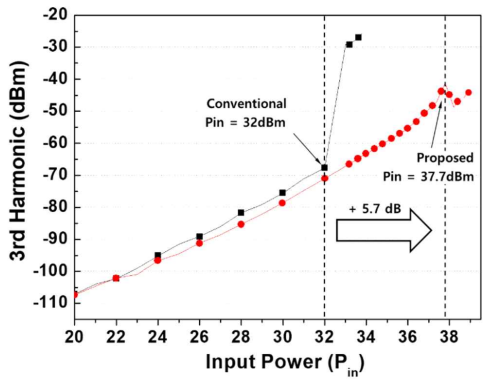

Fig. 5 Power handling level of the proposed switch verified through the 3rd harmonic test.

Figure 6 shows the insertion loss performance with simple equivalent model under the switch one-path on condition (RFP off). The small signal characteristics are almost same compared to conventional antenna switch up to sub6GHz band. From the measurement results, we confirmed that proposed switch has 0.31dB of insertion loss and 42.72dB of isolation at 2GHz. And Conventional case has 0.29dB of insertion loss and 45.11dB of isolation at 2GHz. The degeneration of insertion loss and isolation is only 0.02dB and 2.39dB, respectively.

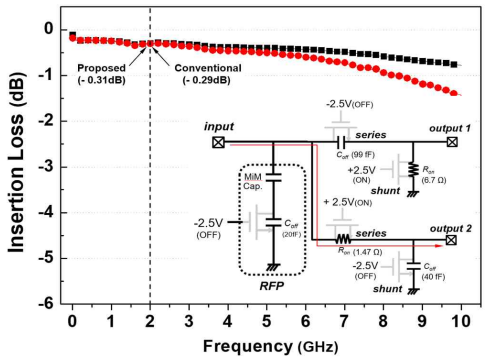

Fig. 6 Insertion loss performance under the switch one-path on condition (RFP off).

Ⅳ. Conclusion

An RF protection technique of antenna switch without critical payment of circuit performances was proposed. By employing RFP scheme, it achieves 37.7 dBm power handling level as high as 5.7 dB compared to the conventional one at 2 GHz. Also, the degeneration of insertion loss and isolation is only 0.02 dB and 2.39 dB, respectively. This work shows that the use of a RF protection to effectively increase the power handling level of all-path off mode switch.

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