DC~18GHz Wideband SPDT Switch

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Abstract. this paper mainly introduces a DC~18GHz wideband SPDT switch . Firstly, every possible configuration is contrasted, the theories of basic GaAs switch configurations are mentioned. Secondly, the theories of basic GaAs switch configurations are mentioned. Subsequently, appropriate topology is selected for this SPDT switch. This switch has been realized by 0.2μm GaAs PHEMT process. this switch exhibits high performance: over DC~18GHz, insertion loss is lower than 2.4dB; The isolation is lower than 45dB; the ripple variation of insertion loss is less than 1.4dB; input return loss is lower than 12dB; on state, output return loss is lower than 13dB; off state, output return loss is lower than 25dB; on and off time are less than 20ns.

Introduction

Wireless communication industry has grown very rapidly in the last decade, there is a great demand for very high speed communication networks. To respond to those demands, an ultra wideband communication technique which enables wireless communications in high speed wide band together with existing wireless communication services is under development.

RF switches are key elements for any transceiver system. RF and microwave switches are extensively used in wireless systems for the main purpose of signal routing. An RF switch allows performing different tests on the system without making connects or disconnects. The applications of switches in radar and communication systems are mainly Tx/Rx switching, band selection and routing the signal between different RF paths. A switch may receive an input signal at one terminal and a control signal. The switch may pass the input signal to the other terminal if it is turned on by the control signal and may block the input signal if it is turned off by the control signal[1~3].

Increasing needs for RF systems covering ultra wideband bands have been leading us to the development of the ultra wideband switch, switches is one of the most crucial components in RF systems.

Circuit design

With the active development and research on wideband SPDT switches, various switches designs have been made to implement the switch available in the wideband.

FIG.1 shows a micro-electromechanical-systems (MEMS) switch, Electromechanical switches generally have low insertion loss and good isolation.They can handle signals at very high power levels. However, their switching speed is slow. Their repeatability is not perfect and they suffer from lifetime. They are also sensitive to vibration. Electromechanical switches are making some new in-roads in the form of MEMS devices . Recent generation MEMS switches have solved many of the reliability and reproducibility problems making them competitive in several applications[4~5].

Solid state switches(Fig.2) have higher ON resistance when compared to their electromechanical counterparts, thus their insertion loss is higher. Their power handling is also worse than electromechanical switches. However, they provide fast switching speeds. They are resistant to shock and vibration. They are also much more reliable. They exhibit longer lifetime. They can also be realized in small size.

PIN diodes were the first widely used solid state switching technology. Providing PIN diodes switch(Fig.3) lower insertion loss and better power handling capability than most IC FETs they are still in wide use today. An important figure of merit for switches, RonCoff product, is usually in the range of 100-200fs for PIN diode switches, which is another fact that makes PIN diodes preferable. However; depending on the thickness of the intrinsic region, PIN diode switches have a limit on operation at low frequencies. Another limitation of PIN diode switches is their power consumption. Since PIN diodes are current controlled devices, they consume more power than voltage controlled FET switches,DC power consumption is need[6~7] .

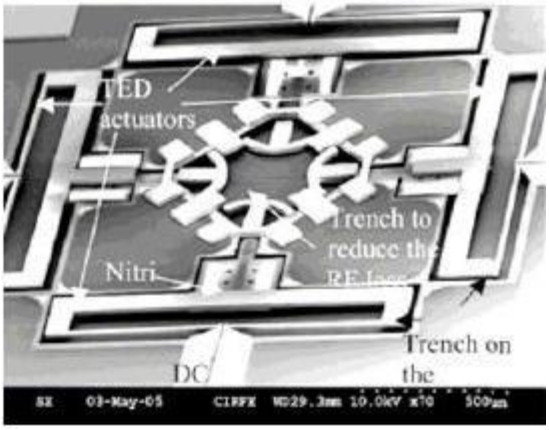

Figure. 1 MEMS Switch

Figure. 2 Solid State Switch

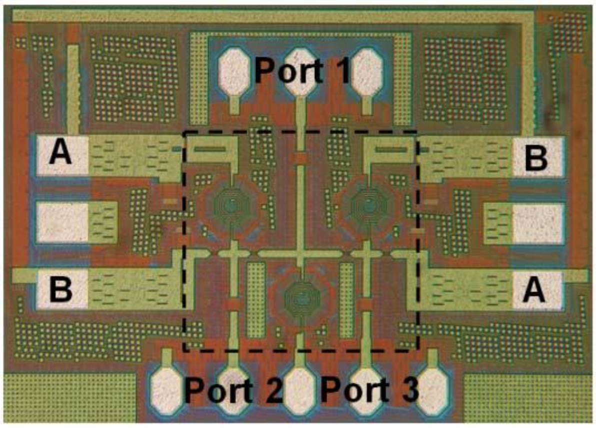

Figure. 3 PIN Diode Switch

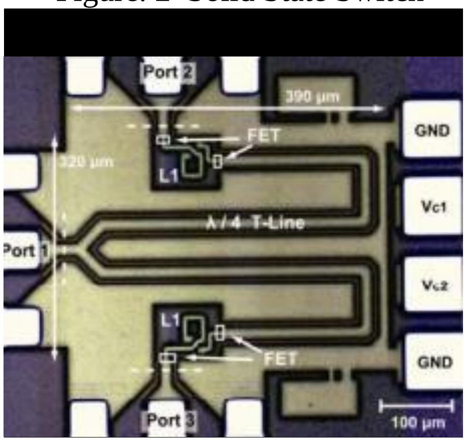

Figure. 4 CMOS Switch

FET switches have started being widely used since the 80s. FET transistors operate as voltage controlled variable resistors. This property makes them useful for applications requiring low power consumption like mobile applications. Their ON resistance is a little larger so their insertion loss is generally higher than their PIN diode counterparts. Referring to FIG.4,a CMOS switch is shown[8~9]. With the development of PHEMT MMIC devices, lower ON resistance than that of MESFET MMICs is obtained; however, they suffer from gate lag which causes the switching time increase to several microseconds while MESFETs can provide switching speeds down to tens of picoseconds. CMOS SOI (silicon-on-insulator) and CMOS SOS (silicon-on-sapphire) do not suffer from gate lag but they still suffer from low switching speeds since they are designed to optimize the tradeoff between low frequency operation and switching speed. With the recent developments, SOS and SOI FET switches have been competing with GaAs switches as their cut-off frequency, breakdown voltages and insulating substrate quality improved. Their linearity also has been improved allowing them to operate at higher power levels. However, the high power territory is still dominated by the PIN diode switches[8~9].

With the use of GaN, the power levels obtained from a single MMIC have been improved in high power amplifier applications. Some GaN suppliers started to release their high power switch products. Although many GaN suppliers have good processing background, processing of GaN is not as mature as GaAs. With the increasing demand for high power switches with less current consumption, GaN seems to be the future technology for especially military and satellite applications.

To summarize the state of RF and microwave switches, the GaAs MMIC is the most widely used technology in medium and low power levels. The wideband SPDT switch has been realized by 0.2 µm GaAs pHEMT process. the excellent performance capabilities of GaAs pHEMT switches configuration as a wideband stage have been clearly demonstrated, GaAs pHEMT switches have low insertion loss with no DC power consumption[10~11].

when PHEMT is ON-state,a small resistance $R_{ON,}$ ideally zeroed, appears between source and drain ports; when PHEMT is OFF-state, the simplified equivalent model shows a high resistance R_{OFF} and a Parallel capacitor C_{OFF} between source and drain ports.

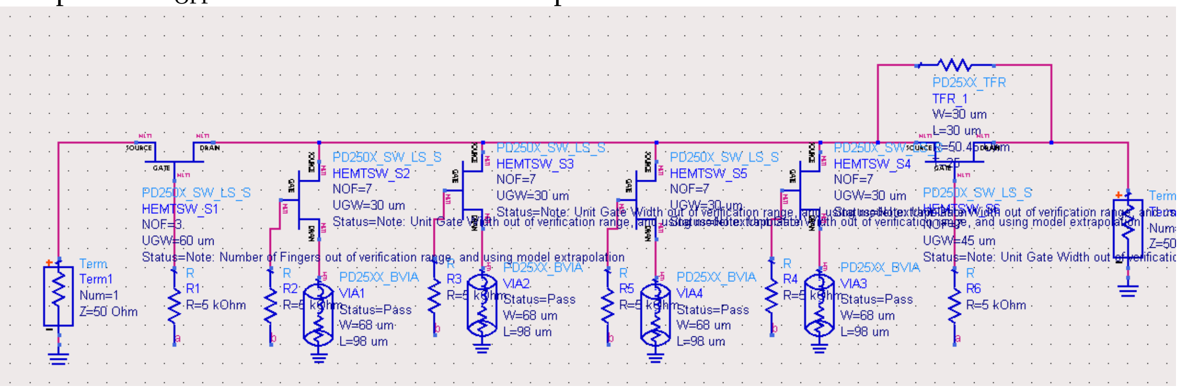

Figure. 5 Wideband SPST Switch

Referring to FIG.5, a wideband SPST switch is shown. pHEMT in series have high insertion loss, high isolation at low frequency, low isolation at high frequency. pHEMT in parallel have low insertion loss with commonly isolation.

Simulation results

The wideband SPDT switch with package have been presented based on the ADS2008. over DC~18GHz, insertion loss is lower than 2.3dB(Fig.6); The isolation is lower than 45dB(Fig.7); the ripple variation of insertion loss is less than 1.4dB; input return loss is lower than 12dB(Fig.8); on state, output return loss is lower than 13dB(Fig.9); off state, output return loss is lower than 25dB(Fig.10); on and off time are less than 20ns.

Figure. 6 Simulated Insertion Loss

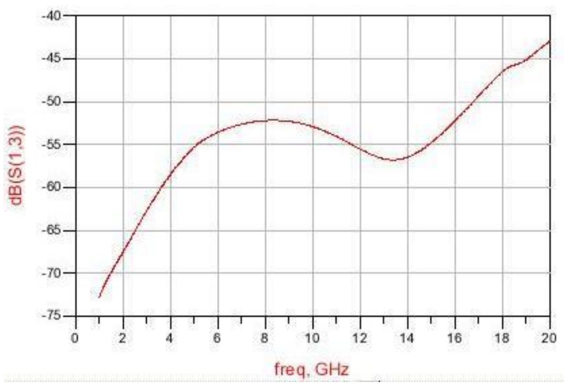

Figure. 7 Simulated Isolation

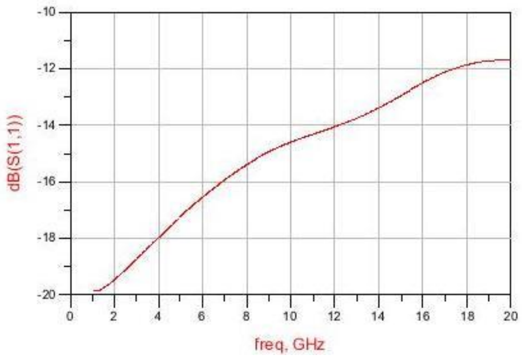

Figure. 8 Simulated Iutput Return Loss

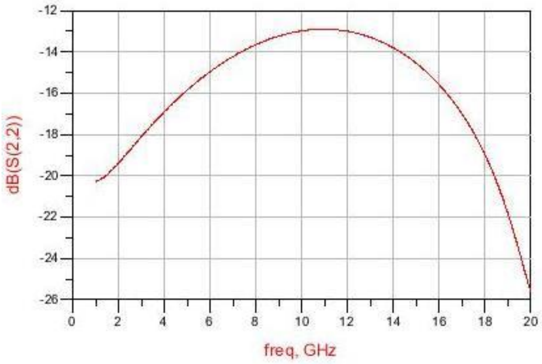

Figure. 9 Simulated Output Return Loss(on)

Figure. 10 Simulated Output Return Loss(off)

Conclusion

References the theory and design of a wideband SPDT switch are presented. To ensure high yield, Performance redundancy optimization strategy is used in design. the results of the developed MMIC chips in the DC~18GHz show that: insertion loss is lower than 2.3dB; The isolation is lower than 45dB; the ripple variation of insertion loss is less than 1.4dB; input return loss is lower than 12dB; on state, output return loss is lower than 13dB; off state, output return loss is lower than 25dB; on and off time are less than20ns. This proposed MMIC has shown excellent performance covering DC~18GHz for wideband SPDT switch.

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