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A 24-GHZ ACTIVE SPST MMIC SWITCH WITH INGAP/GAAS HBTS

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ABSTRACT: *A 24-GHz single-pole, single-throw (SPST) switch with high isolation is designed using InGaP/GaAs HBT process. To obtain high isolation in an off state, cascode structures are utilized and an additional shunt transistor is introduced in an output, which helps to reject a leakage signal. Dummy cascode structure is used as a current steering circuit for input matching and short rise/fall time. The fabricated SPST switch shows an effective isolation of ~52 dB at 22.8 GHz and 41 dB at 24 GHz.* © 2008 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 2155–2158, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23606

Key words: *SPST switch; active switch configuration; high effective isolation; UWB signal generation*

1. INTRODUCTION

Recently, a signal generation block for keeping a wideband characteristic and generating pulse signals efficiently is one of the most important research topics in UWB radar sensor [1]. There are two general methods for the signal generation; one is to generate pulse signals directly using pulse generator or impulse generator, and the other is to use a high speed switch together with a conventional CW signal generator to shape the pulse signal [2]. The latter makes it possible for the radar sensor to operate in FMCW and pulse modes [3]. The important characteristic of the switch required in the signal generation block is isolation because isolation between input and output ports decides the power of a leakage signal when the switch state is off. Because of the limited isolation level, high frequency signals can be transmitted in the unwanted time and the pulse shaping is not properly performed for the radar sensor [4]. In addition, Tx output spectrum violates the Federal Communications Commission (FCC) spectrum mask regulation when Tx leakage signal is over −40-dBm signal power.

In this work, a scheme to place an additional shunt switch at the output load path of cascode type active SPST switch is proposed to improve the isolation characteristic at 24 GHz. The measured results of the proposed switch show the best isolation performance among the active-type SPST switches.

2. SPST SWITCH FOR HIGH ISOLATION

While conventional passive-type switch has high isolation between input and output ports in an off-state and high power capability, it also includes an insertion loss. Moreover, it cannot be applied for the UWB pulse generation using CW signals due to the limit of operating speed. Compared with the passive-type switch, the active-type switch can operate with faster operating speed [5].

Figure 1 shows a schematic of the proposed SPST switch. The switch consists of seven transistors. A turn-on voltage of InGaP/GaAs HBT in the designed circuit is 1.24 V. In the on-state of the switch, control voltage "+Vcont" in Figure 1 is set up to be 1.5 V, and "−Vcont " in Figure 1 is set up to be 1 V. Then Q_1, Q_3, and Q_5 are operating in an on-state and Q_2, Q_4, Q_6, and Q_7 are operating in an off-state as shown in Figure 2(a) because the bias control voltage of Q_2 is lower than the turn-on voltage of a transistor. Q_2, Q_4, and Q_6 as dummy transistors do not have an effect on the switching operation. Input impedance is determined by a parallel circuit consisting of turned-on Q_1 and turned-off Q_2. In the on-state, the SPST switch is operating as a cascode amplifier, so the switch has a voltage gain while a conventional passive-type switch has an insertion loss. In the off-state, Q_4 turns on and Q_3 turns off due to the applied control voltages. So Q_1 and Q_5 are off, Q_2 and Q_6 are on as shown in Figure 2(b). RF input signal is ideally bypassed to the ground and it's not transmitted to output port. But in a real world, the RF signal is transmitted to output port through transistor parasitic. Because the cascode transistor makes high isolation between input and output ports in the off-state, a leakage signal can be decreased greatly [6]. Additional transistor Q_7 in output load is controlled by "−Vcont" and it provides a leakage signal path, which results in the isolation improvement of the switch. Because the input impedance is almost same, regardless of the switch states, the reflected signal power is almost constant in any state of the switch. When the reflected signal power varies with input impedance unsettled by the switch operation, the power spiking can be generated and can damage the signal source. To minimize the switching time, the current steering technique is used for the switch design [7]. Q_2, Q_4, and Q_6 are dummy transistors for the current steering technique of high-speed operation.

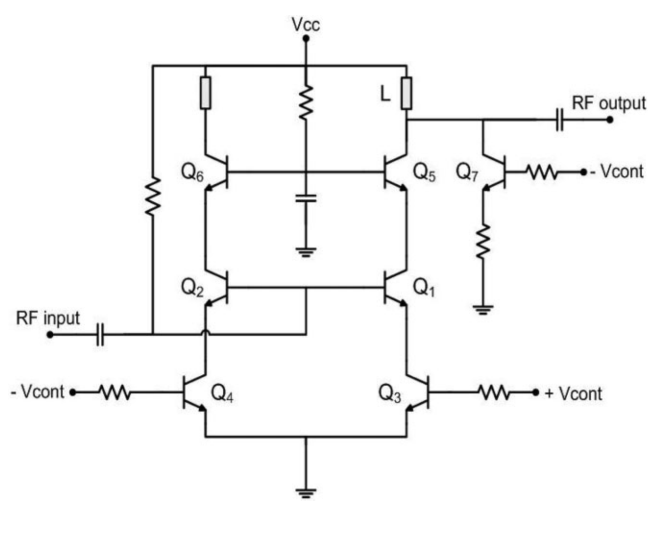

Figure 1 A schematic of the SPST switch with high isolation using HBT process

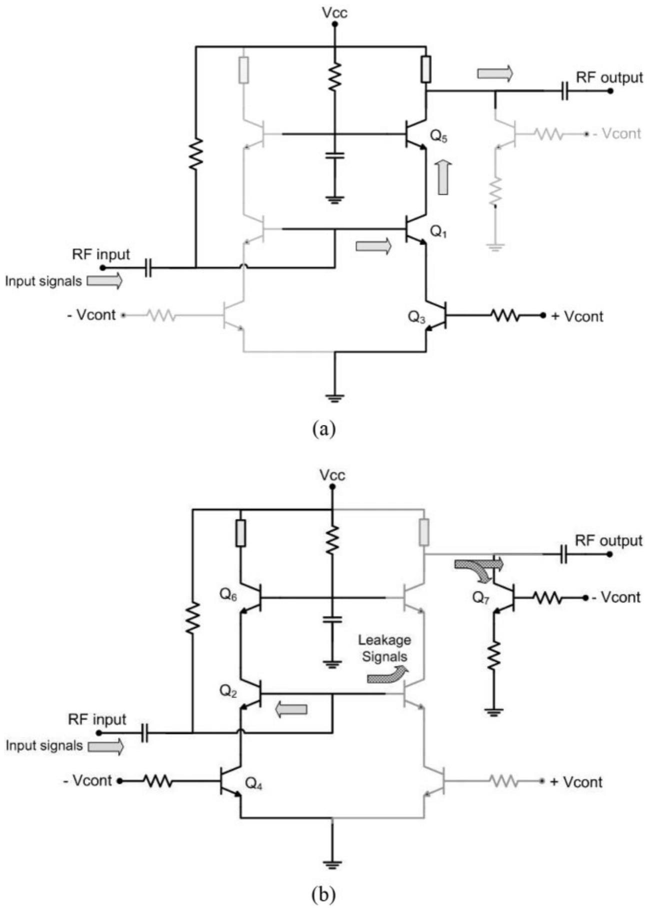

Figure 2 Operating diagram of the switch: (a) in an on state and (b) in an off state

Therefore the proposed SPST switch makes the input matching keep stable regardless of the switching operation mode. And the isolation of the proposed switch is increased by the cascode configuration and additional output shunt transistor. There is power consumption in the active-type switch, compared with the passive-type SPST switch, but the voltage gain and high speed switching operation are achieved.

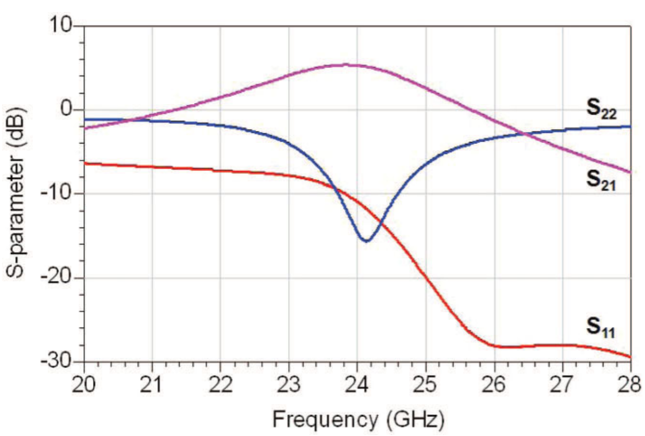

Figure 3 Simulation results in the on state of the switch including parasitic effects by using 2.5 D EM simulator. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

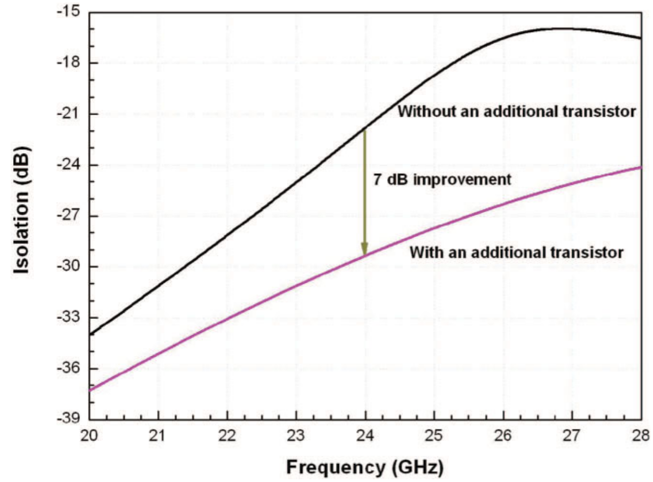

Figure 4 Simulation results of isolation in the off state of the switch including parasitic effects by using 2.5 D EM simulator. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

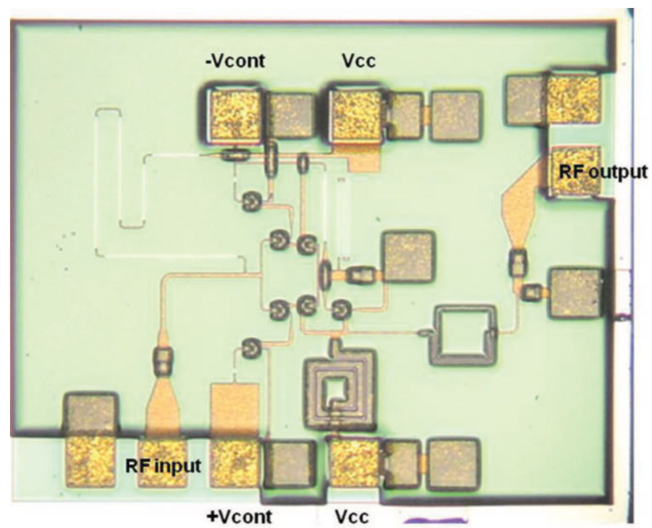

Figure 5 Chip photograph of the MMIC SPST switch. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

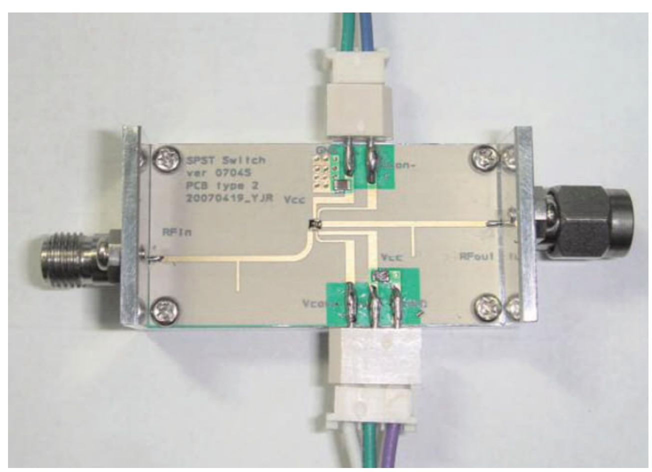

Figure 6 Switch module photograph for the measurement. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

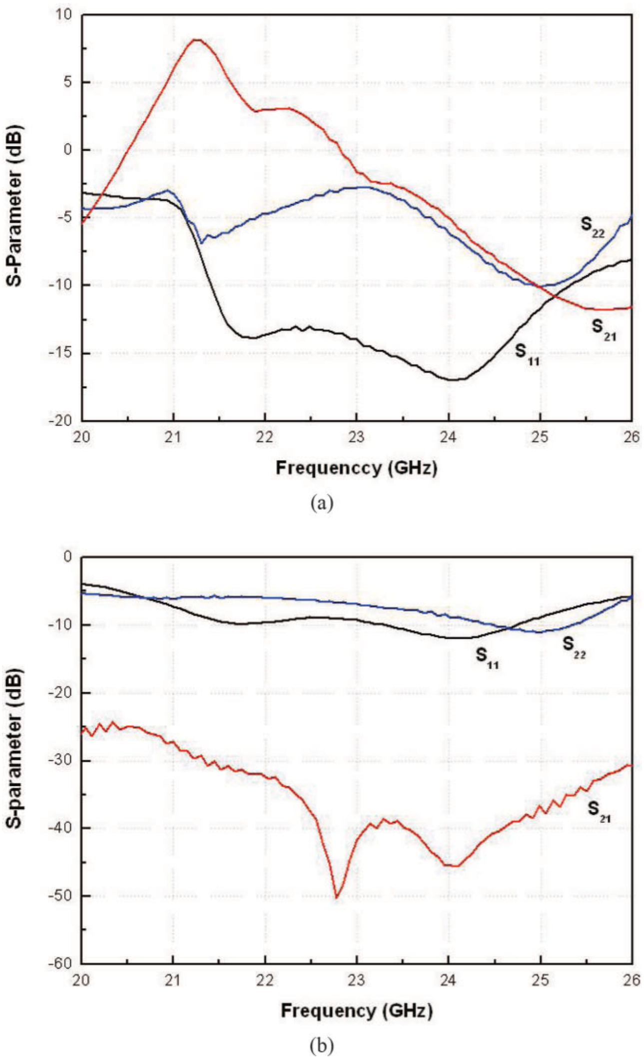

Figure 7 Measurement results: (a) in an on state and (b) in an off state. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

3. SIMULATION RESULTS

The proposed SPST switch is designed at 24 GHz using Agilent ADS simulator. Figure 3 shows the simulation results in the on-state of the proposed switch using schematic models with 2.5 D EM simulation data. As shown in Figure 3, the switch operates as a cascode amplifier with 5.1-dB gain. Compared with the switch without Q_7 in Figure 4, the off-state isolation performance of the switch with Q_7 is improved by 7 dB. P_{1dB} is simulated to be 0.513 dBm at 24 GHz. When the control signal has the rise and fall time of 10 ps, the output signal of the switch has rise and fall time less than ~100 ps in time-domain simulation with EM results of transmission lines.

4. MEASUREMENT RESULTS

The SPST switch is fabricated using InGaP/GaAs HBT process with 65-GHz cut-off frequency. The chip size is 1.7 × 1.6 mm^2. Figure 5 shows the chip photograph. For the measurement, the switch module is implemented on high frequency PCB, RO3003 as shown in Figure 6. Open stub lines are made on the PCB to compensate bonding wire inductance of the MMIC switch. So frequency performance in measurement results of the module can be the same as that of the MMIC switch. The measurement results of the module in Figure 7 contain ~1-dB signal loss due to transmission lines and two K-connectors. Power consumption is 10 mW irrespective of switch operating states. As shown in Figure 7, the center frequency of the switch in the on state is downshifted about 2 GHz compared with that of simulation results. The model parameters of the HBT process are provided up to 20 GHz, so they have some fitting errors in 24-GHz region. That could make the frequency shift in the switch, especially because of the parameters of the transistor and inductor. The maximum performance of 2.0-dB voltage gain and −50.2-dB isolation is obtained at 22.8 GHz. At desired center frequency of 24 GHz, the voltage gain of −4.4 dB and isolation of −45.4 dB are measured. When the effective isolation can be defined by the difference between gain and isolation, the effective isolation of the switch is −41 dB at 24 GHz and −52.2 dB at 22.8 GHz.

Table 1 summarizes performance comparison of the proposed switch and the other SPST switches reported in the literatures. Our work has better effective isolation and lower power consumption than the other active-type SPST switches.

5. CONCLUSION

The 24-GHz SPST active switch is implemented using InGaP/GaAs HBT process. The isolation of the switch is improved by 7 dB in simulation results by using the cascode dummy transistors and the additional shunt transistor. Utilizing this structure, the effective isolation of 52.2 dB at 22.8 GHz and 41.1 dB at 24 GHz is achieved in the fabricated SPST switch. The 52.2 dB isolation at 22.8 GHz is the best performance in the active-type SPST switches. The switch can also operate with faster switching time due to current steering circuit topology.

TABLE 1 Performance Comparison of the SPST Switches

				This Work	
	[8]	[9]	[10]	Simulated	Measured
Type	Passive	Active	Active	Active	
Process	GaAs	SiGe BiCMOS	SiGe BiCMOS	InGaP/GaAs HBT	
Center frequency	24 GHz[a]	24 GHz[a]	23 GHz	24 GHz	22.8 GHz
Gain	−1.0 dB	1 dB	−0.3 dB	5.1 dB	2.0 dB
Effective isolation	41 dB	33 dB	42 dB	34.3 dB	52.2 dB
P1dB	33 dBm	–	0.5 dBm	0.513 dBm	–
Power consumption	0	60 mW	50.5 mW	9.1 mW	10 mW
Switching time	4 ns	60 ps	100 ps	100 ps	–

[a] A center frequency is set at 24 GHz for performance comparison.

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GENERATION OF DISPERSION-FREE MILLIMETER WAVE SIGNALS BY DOUBLE SIDEBAND MODULATION AND VESTIGIAL SIDEBAND FILTERING TECHNIQUES

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ABSTRACT: *Fiber dispersion in standard single mode fiber (SSMF) limits the maximum delivery distance for the optical millimeter (mm)-wave signals generated by double sideband modulation and vestigial sideband filtering. We propose and experimentally demonstrate a novel scheme to generate mm-wave signals without dispersion limitation. The power penalty for 2.5-Gbit/s mm-wave signals carried by 40-GHz radio-frequency after transmission over 80-km SSMF is smaller than 0.5 dB.* © 2008 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 2158–2161, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23605

Key words: *optical mm-wave generation; vestigial sideband filtering; radio-over-fiber; power penalty*

1. INTRODUCTION

To generate low-cost optical millimeter wave (mm-wave) is one of key technologies to make radio-over-fiber (ROF) systems practical for commercial deployment. Recently, a few new methods for generating optical mm-waves are reported [1–15]. Optical mm-wave generation using optical double sideband modulation scheme has a simple configuration [1, 2]. However, due to the fiber dispersion, the RF signal will be faded, and the maximum delivery distance is limited to 1–2 km [14]. Reference 14 reported a scheme to overcome this fading effect by using vestigial sideband (VSB) filtering. However, there is around 2-dB power penalty after transmission over 40-km standard single mode fiber (SSMF) and the maximum transmission distance is limited to be shorter than 60 km by fiber dispersion. In this letter, we propose and experimentally demonstrate a novel scheme to overcome the fiber dispersion and realize dispersion-free mm-wave signal transmission.

2. PRINCIPLE

Figure 1(a) shows the scheme demonstrated in Ref. 13. In this scheme, two cascaded external modulators are employed. The first external intensity modulator is driven by RF signal. Then it is remodulated by another intensity modulator driven by a baseband signal. In this way, the baseband signal is up-converted. One optical filter is employed to realize VSB filtering. After the optical filtering, one first-order sideband is removed and only optical carrier and another first-order sideband are kept. Since both the remained optical carrier and the sideband carry the same data, they will be suffered from the fiber dispersion when they are transmitted in the fiber because they will have different group velocities in fiber. Figure 1(b) shows our proposed novel scheme. The electrical baseband signal is up-converted by an electrical mixer; then it is used to drive the intensity modulator. By this scheme, only the sideband carries the RF signal, while the optical carrier does not carry RF signal. After VSB filtering, only the optical carrier and

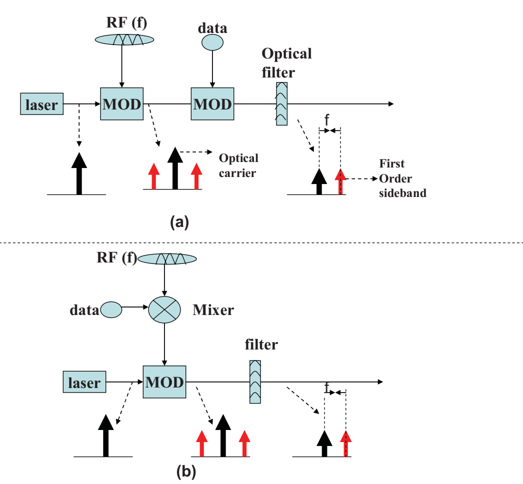

Figure 1 Two different schemes for mm-wave signal generation based on DSB plus VSB techniques. (a) Scheme in Ref. 13; (b) our new scheme. MOD: external modulator. We assume the repetitive frequency of the RF is f. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]