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High Performance SOI RF Switch for Healthcare Application

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ABSTRACT

The objective of this research was to design a 0-5 GHz RF SOI switch, with 0.18um power Jazz SOI technology by using Cadence software, for health care applications. The ultimate goal for such application is minimize the trade-offs between performance and cost, and between performance and low power consumption design. This paper introduces the design of a RF switch implemented in shunt-series topology. An insertion loss of 1.36 dB and an isolation of 58.5 dB were obtained at 5 GHz. The switch also achieved a third order distortion of 57.12 dBm and 1 dB compression point reached 38.83 dBm. The performance of the RF switch meets the specification requirements of the desired.

Keywords: Shunt-series, RF switch, isolation loss, insertion loss.

1. INTRODUCTION

Wireless medical sensor networks have offered significant improvements to all area, especially the healthcare industry in the 21st century [1][2][3]. Devices are arranged on a patient's body and can be used to closely monitor the physiological condition of patients. From the fundamental of the material to the highest architecture level, researches are working super hard, and the improvements can be seen here [4][5][6][7][8][9][10][11].These medical sensors monitor the patient's vital body parameters, such as temperature, heart rate, blood pressure, oxygen saturation, and transmit the data to a doctor in real time [12][13][14][15][16][17]. When a doctor reviews the transmitted sensor readings, they can get a better understanding of a patient's health conditions. The benefit for the patients is that they do not need to frequently visit the hospital, thus patients could reap time and money savings. Such wireless medical sensors will continue to play a central role in the future of modern healthcare[18][19][20][21][22]. People living in rural areas would especially benefit, since 9% of physicians work in rural areas while almost 20% of the US population lives there [2]. A shortage of physicians and specialist is a big issue in such areas, even today. But wireless medical sensor network technology has the potential to alleviate the problem [23][24][25][26].

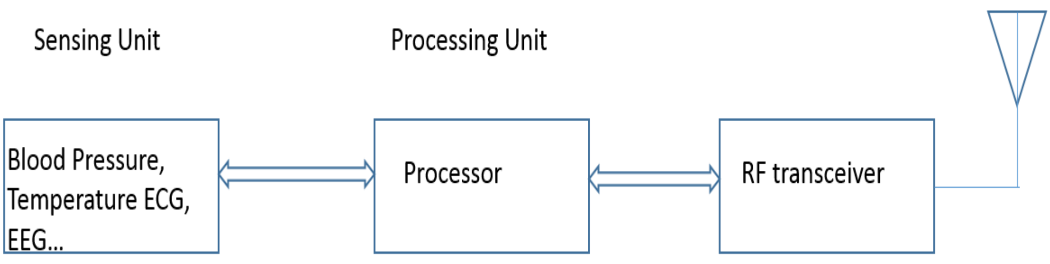

Figure 1: Block diagram of a typical sensor node

Fig.1 shows that the basic sensing node can collect the physiological signals (e.g.: such as EEG, ECG, body temperature, blood pressure, heart beat etc.), when attached to a human body [26][27][28]. The processing unit processes all the sensed signals, then sends out the data based on communication protocols. All the processed data will be transmitted through a wireless link to a portable, personal base-station. Doctors can then obtain all the patients' data through the network.

The main challenge for such sensor node is the high power consumption of portable devices. A solution to this challenge is the integration of the portable devices' digital and RF circuitry into one chip.

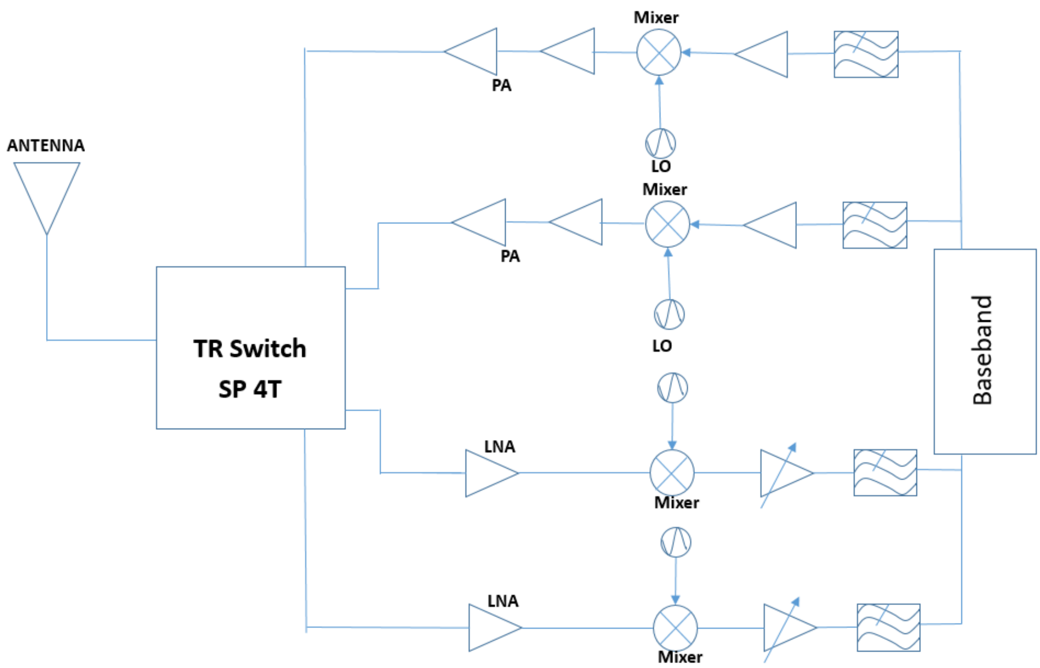

Figure 2: Block diagram of a multiband RF transceiver

The receiver will receive the signal and will also perform DSP processing after the data is sent out by the transmitter [27]. Fig. 2 is the transceiver diagram. It is desirable that the transmitter and receiver are low power devices. The director-conversion transmitter is very popular for such applications, because it offers versatility, flexibility, spectral efficiency, and low complexity. These features make the transmitter simpler than the super-heterodyne transmitter.

To reduce the cost, LNA, mixers, and VCOs usually use Si for manufacture. Since RF switches are also part of such chips, RF switches are also made using Si processes. But there is one issue with this approach: switch breakdown. The main reason is that the voltage can be on the order of twenty volts, however this is much higher than a normal Si transistor can handle. Stacking FETs together is one solution to this problem. Stacked FETs are configurations where the drain terminal and the next source terminal are connected together. Such a topology can make spread a high voltage across multiple transistors, requiring each individual transistor to experience a relatively lower voltage. This kind of design would cause other problems, which include drain-to-ground capacitance. Since several transistors are stacked together this capacitance is not even. So the top transistor has to be larger to avoid a potential large voltage failure.

This paper is mainly for the RF switch design, since other portions of the circuit design are already discussed in the paper [26][27][28][29]. In order to meet the standards, the RF switch is designed as shown in Table 1.

Table 1: RF switch Design Requirement

Parameter	**Size (Unit)**
Frequency	0-5G
Insolation loss (dB)	0-1.2 (dB)
Isolation (dB)	>40 dB
IIP3 (dBm)	55 dBm
P1dB (dBm)	30 dBm

2. BACKGROUND

FET switches usually have three different topologies, such as series, shunt and combinatorial topology. Due to modern, complicated requirements, users for in health care usually require the combinatorial topology to meet their stringent requirements, as seen in the Fig. 3. When a control voltage is set high, the series FET would be on, which means a signal would pass to the following transistor, where a shunt FET would connect to the ground. When the control is set low, the series FET is off, so there will be no signal flow through the transistor, however the shunt FET will pass the signal.

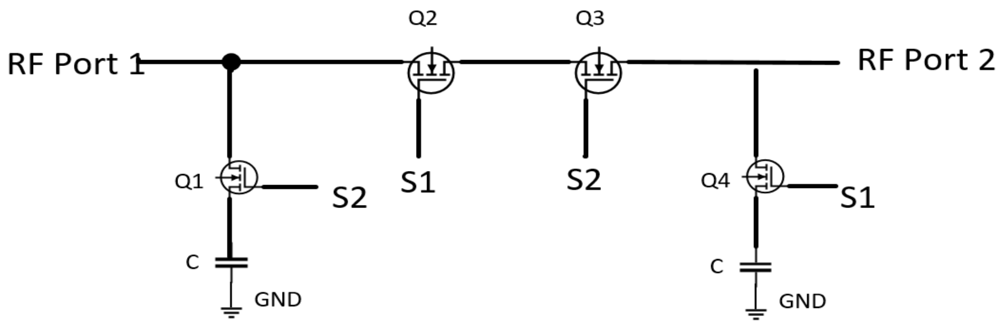

Figure 3: Combinational series-shunt FET switch

In terms of RF switch performance, there are several key parameters, such as reflection coefficient S11, insertion loss S21 and isolation S31[28].

S11 is the input reflection coefficient, which is voltage ratio of the reflected wave on the input port to the original wave. This parameter represents the power loss from impedance mismatches, also known as voltage standing wave ratio (VSWR).

S21 represents the forward voltage gain. A low insertion loss between source and active switch is critical to increase the efficiency.

S31 is also a very important switch parameter. When there is 3 ports, two ports are on, and another port is off, and this parameter is a measure of the transmission coefficient from the source to the off arm. This parameter represents how much power was leaked into the off arm.

Besides the S11, S21, S31, a switch design's value must also consider the intercept point (IP3). This parameter is a measure of the linearity of a device, which also known as intermediation distortion. The third order intercept point is where the intercept of the fundamental frequency and the third order of the fundamental frequency.

There are many other parameters that can be considered, but the S-parameters and the IP3 are the critical ones that must often be considered. A good RF switch usually possesses: low insertion loss, high isolation, high power handling, and very high ESD immunity.

3. DESGIN

FETs are three terminal devices are usually fabricated as SOI or GaAs. The basic function is shown in Fig. 3[28]. When the gate is more positively biased then the source, a channel would be formed between the source and drain side, so the resistance is lowered, and a current can be flowed between source and drain terminals. However, if the gate voltage is equal or smaller than the source terminal, no channel will form, resistance will be much higher, and no current flows through channel.

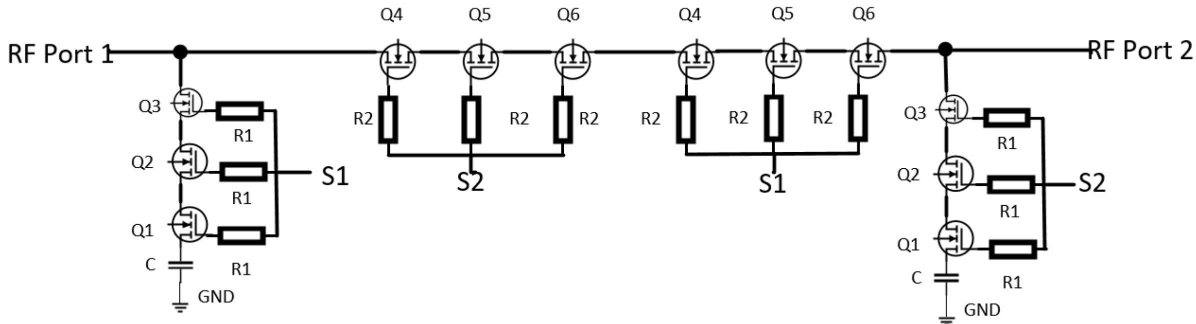

Figure 4: Modified series-shunt FET switch

The SPST switch was used for the healthcare application which can worked for the 0-5 GHz, so it required designed high isolation and moderate insertion loss. A proposed topology is shown in Fig. 4 which is based on shunt-series configuration. Such type of topology slightly different from Figure 3 when only using a single series-shunt topology [29]. When using two shunt transistors Q1 and Q3, it can provide higher isolation than one transistor. However, the two shunt arm transistors would also decrease the insertion loss. Besides for improving the S11, the impedance matching circuit is needed to improve. To compensate for the insertion loss degradation, isolated triple-well (TW) devices were used for the series arms (Q2 and Q4) [30]. The devices were sized to fulfill high isolation and also acceptable insertion loss at the bandwidth of interest, which is 0-5 GHz. The detailed sized can been seen in the Table 2.

Table 2: RF switch Component

Parameter	Size (Unit)
Q1,Q2,Q3	W/L=10um/0.28um (f=100,m=40)
Q4,Q5,Q6	W/L=10um/0.2um (f=20,m=40)

4. RESULTS

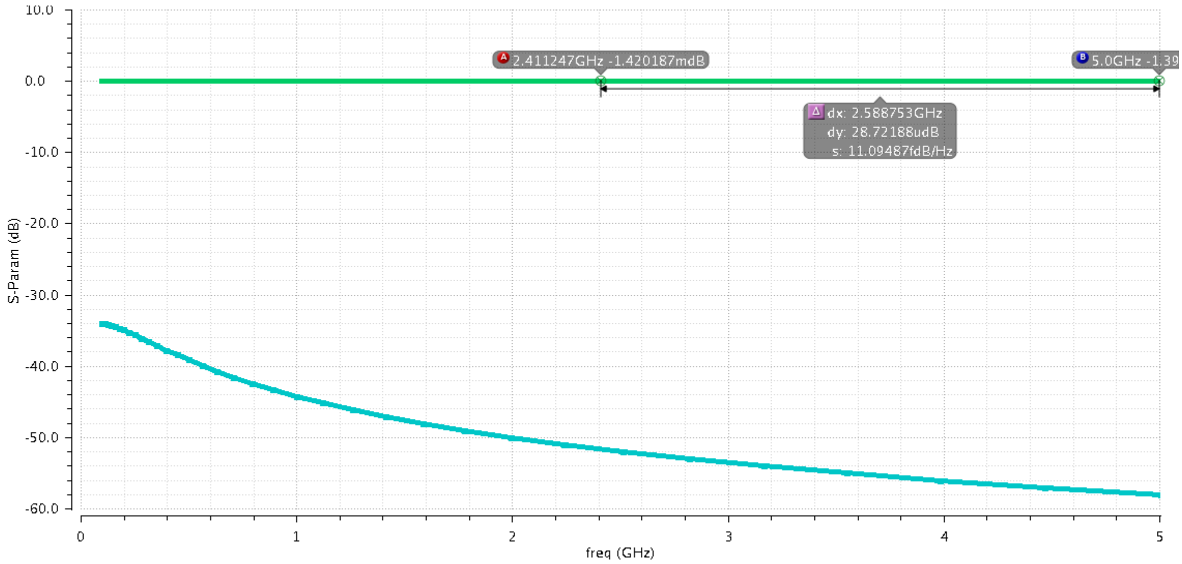

Figure 5: Insertion (green) and isolation (blue)

As seen in Fig. 5, an insertion loss of 1.36 dB and an isolation of 58.5 dB were obtained at 5 GHz.

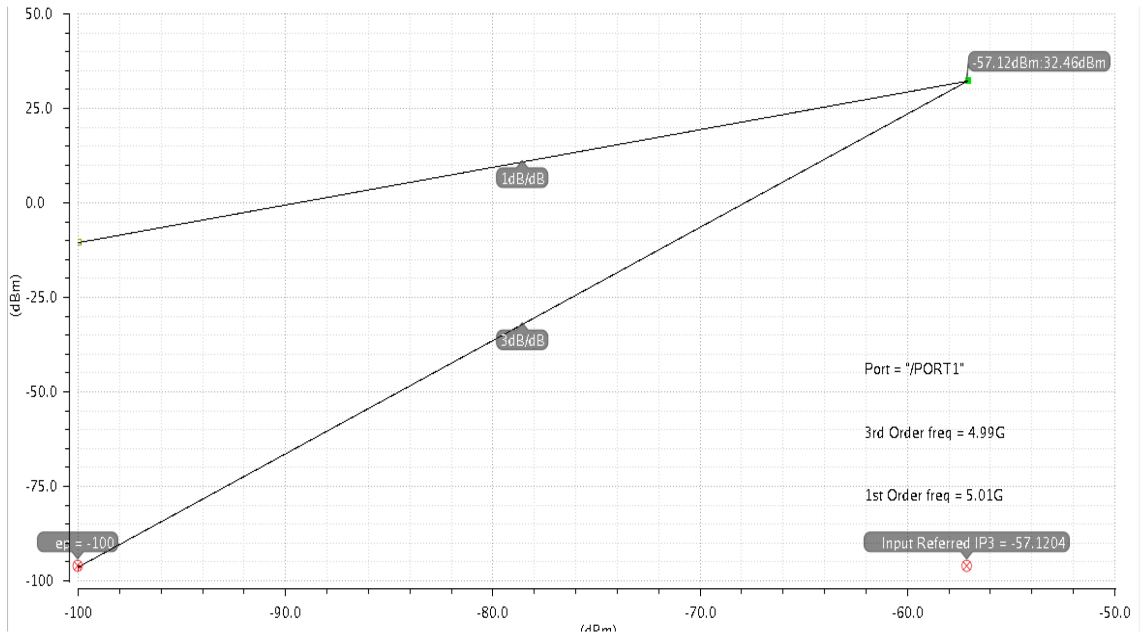

Figure 6: IIP3

As seen in Fig. 6, input referred IP3 reached 57.12 dBm.

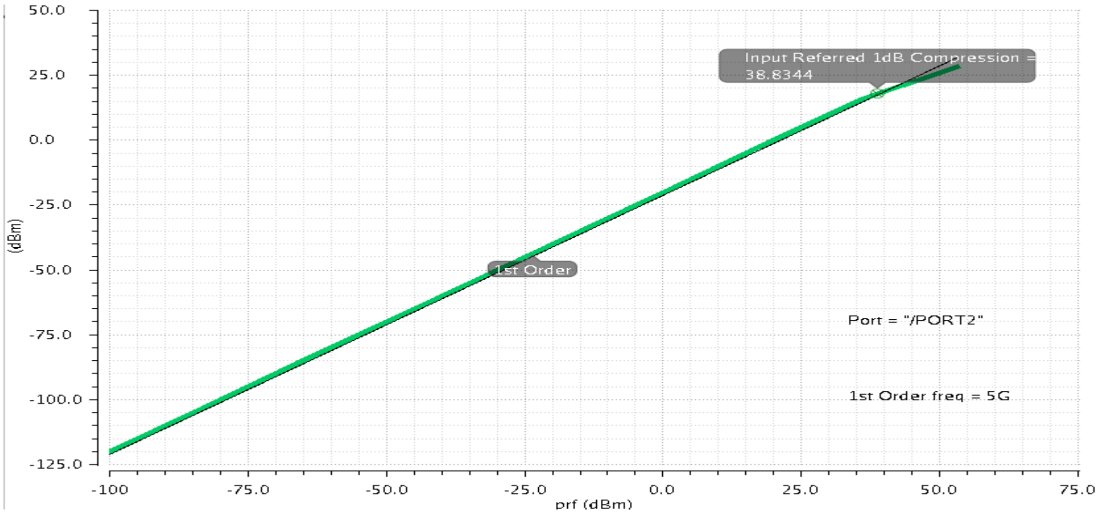

Figure 7: P1dB

As seen in Fig. 7, 1 dB compression point reached the switch achieved a third order distortion of 38.83 dBm.

CONCLUSION

This paper describes the method of designing and simulating RF switch using cadence software based on Power Jazz SOI process 180nm technology. This RF switch is used for sensor networks. This research is still in the early stages of development of a low cost and low power device. This circuit meets the scheduled requirements for the SOI process, but it still has room to improve performance metrics. When the sensor is coupled with communications technologies such as mobile phones and the Internet, the sensor network constant information flow between individuals and their doctors[32][33]. Such low cost and low power device can save a lot of hospitalization resources.

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