Total Ionizing Dose (TID) effect test of developed 2.5 GHz radiation hardened Clock Multiplier Unit (CMU)

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Introduction

A radiation harden 2.5GHz clock multiplier unit (CMU) in 0.18µm UMC process has been designed and developed as a sub-block of 10 bit serializer and de-serializer(SERDES) operating at 2.5Gbps. The CMU will deliver a clock with very little jitter (< 1ps) to the SERDES which will located next to the detector of CBM experiments [1].The most upstream detector station of MUCH will receive the highest dose of 300Gy/2months as has been simulated by FLUKA calculation and total CBM-MUCH operating period in 10 years is expected to be of 20 operational months [2], and therefore the CBM readout electronics are to be made to withstand the total dose of 315krad. To make sure that CMU will work in this environment, we have performed Gamma irradiation dose testing on the proper setup of ^{60}Co chamber at UGC-DAE Consortium for Scientific Research, Kolkata.

Design and development of CMU

The design of CMU is based on the principles of phase locked loop (PLL), specific architecture design and techniques are implemented to help to mitigate radiation effects that degrade PLL performance [3].The block diagram of CMU is shown in Fig 1.

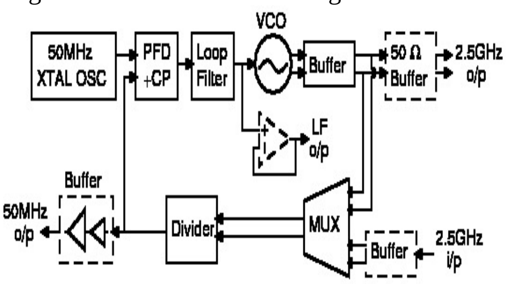

Fig. 1 Block diagram of clock multiplier unit

The PLL consist of Phase and Frequency Detector (PFD), charge pump, a loop filter, the LC tank Voltage Controlled Oscillator (VCO), frequency divider, The developed radiation hard PLL uses the UMC 180 nm Silicon on Sapphire (SOS) CMOS process technology. The detail design description of CMU is available in the report [4]. CMU has been designed with the options so that individual block level testing as well as full PLL testing can be performed. The circuits and circuit elements are chosen by studying the effects of radiation on them and means of countering them and the at the layout level guard rings are used to reduce the effects of radiation on circuits [5].The main radiation effects on MOSFETs include the changes in the threshold voltage and mobility, which causes the drain current to decrease. As a result, the phase noise and tuning range of PLL are degraded. The PLL design layout and developed CMU ICs with test circuit are shown in Fig 2.

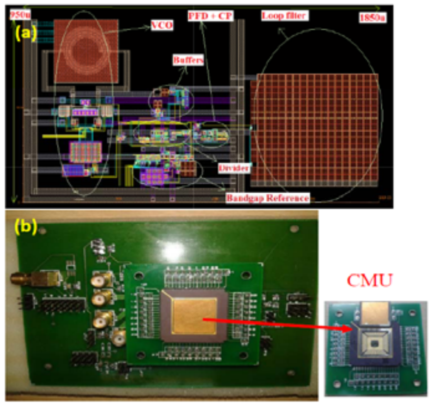

Fig. 2 (a) Layout of PLL (b) Test setup for developed CMU

Measurements and Testing

The test of CMU without radiation has been performed for VCO standalone mode as well as PLL in lock-in mode. The measured spectrum is shown in Fig 3(a). The measured phase noise with decade of frequency 1 MHz is ~108.5 dBc/Hz. The measured output power of 2.5 GHz signal is ~ 17 dBm. Switch capacitor arrays are used in design in order to provide coarse tuning of the frequency of VCO. The tuning performance during simulation has been found from 2.0 GHz to 2.89 GHz while the measured tuning range of the VCO is around 2.0 GHz to 2.5 GHz which shown in Fig 3(b).

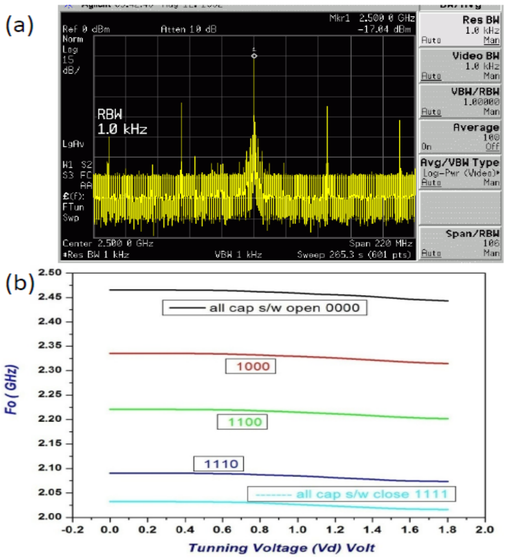

Fig. 3 (a) Frequency Spectrum (b) Tuning test

Gamma irradiation Test

In order to study the radiation effect of gamma dose on the CMU, ^{60}Co Gamma chamber has been used as a irradiation source as shown in Fig. 4(a). The dose rate inside this chamber was of 2.574 kGray/hour.

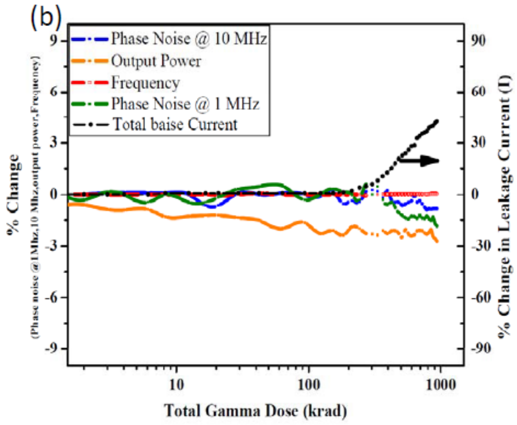

Fig. 4 (a) Gamma irradiation test setup (b) Dose characteristic of CMU

The CMU test circuit board was inserted in this chamber. A DC power cable for connecting the biasing power supply (1.8V) and a low attenuation coaxial cable inserted into the chamber to measure the output signal from CMU. The frequency drift, output power, phase noise and the total current of biasing power supply have been measured with every dose intervals.

Fig. 4(b) shows the performance of CMU with cumulative gamma dose up to 900krad. The total current of biasing power supply increases less than 10% up to 400krad and ~40% for 900krad. The frequency shift is ~ 0.2% for 900kRad dose. The 1MHz corresponding phase-noise is decreased ~ 2% for 900krad. The output power also degrades up to 2.5% for 900krad. The radiation tolerance performance of CMU is well within the acceptable range for gamma dose.

Acknowledgements

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