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Design and Analysis of Ultra Wideband Pulse Generator for Wireless Body Area Networks

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ABSTRACT

The paper presents the design of three configurations of ultra wideband (UWB) pulse generators for short range wireless communications. A low power IEEE 802.15.6 2.4 GHz wireless body area network (WBAN) technology implemented with UWB pulse generators. UWB transmit-only system uses a short pulse width of UWB pulses to achieve low power consumption without multipath fading and interference. The first configuration consists of tunable pulse generator, which consumes power of about 5.4 µW. In the next configuration, the resistive sensing UWB pulse generator controls the voltage in a voltage control ring oscillator (VCRO), and it consumes power of 0.15 µW, at a frequency of 45 MHZ. The third configuration is capacitive sensing UWB pulse generator generates power of 0.132 µW at 250 MHz frequency. The simulation results obtained show that the performances of these UWB pulse generators satisfies the required FCC constraints.

Keywords: Capacitive sensing, Resistive sensing, Tunable pulse generator, Voltage controlled ring oscillator (VCRO), Ultra wideband (UWB), UWB transmit-only system, Wireless Body Area Network (WBAN) .

INTRODUCTION

ULTRAWIDEBAND (UWB) is a radio technology, with bandwidth less than 500 MHZ or 20% arithmetic centre frequency. UWB technology employed in various fields such as radar, sensing and military applications. It has attracted the world because of its wide range use in various wireless communication techniques. The power spectral density (PSD) masks defined for the UWB is −41.3 dBm/MHz. It coexists with other wireless communication systems without interference. In February 2002, the FCC issued that UWB could be used for data communications, imaging and location detection applications are focussed in. The new UWB technology has vast potential for achieving low power and low-cost radio. UWB pulse assures secure communication for preventing eavesdropping of reliable information. The information transmitted using baseband pulses, without a carrier signal.

UWB defined FCC in three different bands of 0-960 MHz, 3.1-10.6 MHz and 22-29 MHz of signal bandwidth. This paper focuses on the first band of the UWB, which has a higher transmit distance, less power, with compact system implementation. It is suitable for low data rate applications such as WBAN, wireless sensor networks, RF-ID, portable instrumentation and other wireless applications are stated. The new WBAN provides a relationship between connectivity and miniaturization of the devices. It consists of devices, which is placed or implanted in the human body. It serves a number of areas, but highly used in the field of the medical electronics. The FCC has approved for the allocation of 40 MHz bandwidth for low power medical Body Area Networks in the 2360-2400 MHz unlicensed bandand applicable in all locations. The low power radio technology such as Bluetooth, ZigBee cannot meet this stringent constraint of the WBAN. The UWB technology adapts to the power requirement of less than 100µW for WBAN applications. In the UWB system, the considerable complexity on the receiver side has enabled the development of the ultra-low power and low complex UWB transmitters for the uplink communication. In this paper, we present the design and analysis of measured results of an integrated FCC compliant UWB transmitter that exhibits high efficiency. The proposed transmitter can be controlled to operate in three different bands of the UWB FCC regulations. To the best of our knowledge, the design presented here is the low power transmitter reported in this range of pulse rates.

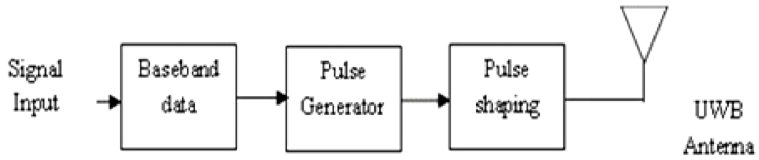


Figure.1.UWB Transmitter

UWB Transmitter: The block diagram of the UWB transmitter shown in Fig. 1 which consists of the pulse generator, pulse shaping circuit and an antenna. The proposed pulse generator generates the pulses with the desired centre frequency and bandwidth. It can adjust the pulse width. This adds flexibility and applicable for different UWB applications [6]. The gating pulse measures the power spectrum of the transmitted signals.

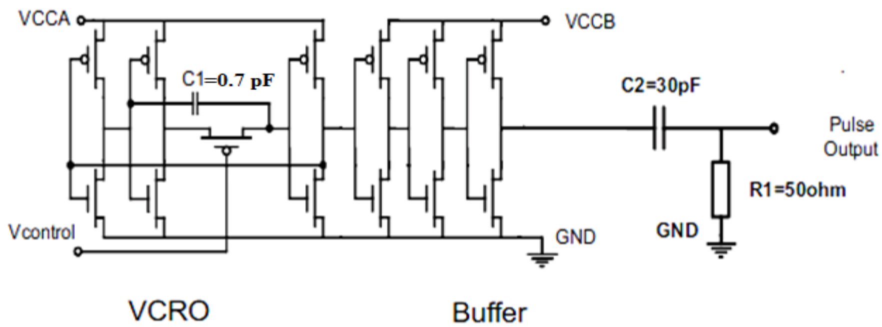


Figure.2.Tunable pulse generator

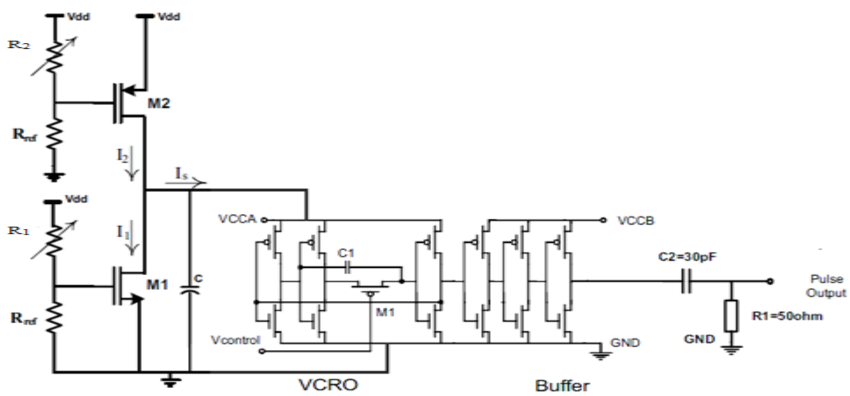


Figure.3.Resistive sensing UWB pulse generator

The fundamental part in the pulse generator is the voltage controlled oscillator (VCO) and the buffer element. The type of the VCO used in the proposed pulse generator is the voltage controlled ring oscillator (VCRO). The VCRO used because of its frequency of operation between the MHz and GHz's. The steady oscillations in the ring oscillator require a total phase shift of 360^0, with the loop gain greater than 0 dB. The buffer designed to make sure that the enough current enters the pulse shaping module. The number of buffer stages modified, to reduce the total power consumption. The antenna made compatible with the transmitter, to suit the power requirements of the pulse generator.

The Proposed Pulse Generators: The pulse generator is an essential unit in the UWB transmit only system. It is the most critical block in terms of the power and frequency requirements. Due to the simple generation and tenability of the gaussian pulses; they are very popular in the UWB technology. These gate pulses do not have the dc component, maintains antenna radiation efficiency and have wide 3-dB bandwidths. It spreads the energy in the frequency range; minimizes the PSD and interference. In this paper, the three proposed configurations of the UWB pulse generators are discussed. The three pulse generators includes the tunable UWB pulse generator, resistive sensing UWB pulse generator and the capacitive sensing UWB pulse generator.

Tunable UWB Pulse Generator: The desirable features of the UWB pulse generator is the tuning capability of the pulses. This ability attains the tunable pulse width, pulse amplitude and transmit power in the circuit. Fig. 2 shows the schematic of the tunable UWB pulse generator. It is composed of two components: the voltage control ring oscillator (VCRO) and output buffer. The heart of the proposed pulse generator is the ring oscillator. The VCRO with the auxiliary delay paths is employed for obtaining higher oscillation. The output of the VCRO is fed to the buffer stage. The buffer stages are reduced to obtain lower power consumption.

The pulse generator is implemented with the three stage inverter based ring oscillator and output buffer with three inverters. The pulse shaping circuit is added with this circuit to obtain a low power gaussian pulse output without interference and reduces noise. The control voltage tunes the pulse and regulates the frequency measurement.

The fig. 3 shows the output pulses of the tunable pulse generator simulated using the tanner tools. The gaussian output produced with ease in generation, smooth transition in the time domain and better frequency response. The offered pulse generator includes the pulse shaping part, three buffer stages and three VCRO stages. The output voltage of 0.9v and current of 6µA is produced, for the control input voltage of 1.5v. The total power consumption in the pulse generator is 5.4µW. The previous work used buffer with four stages and three VCRO stages. The output is a monocycle pulse of 0.7v pulse amplitude and total power of 75 µW, with 1.5v control input voltage. The pulse output was produced without the use of the pulse shaping circuit using Spice.

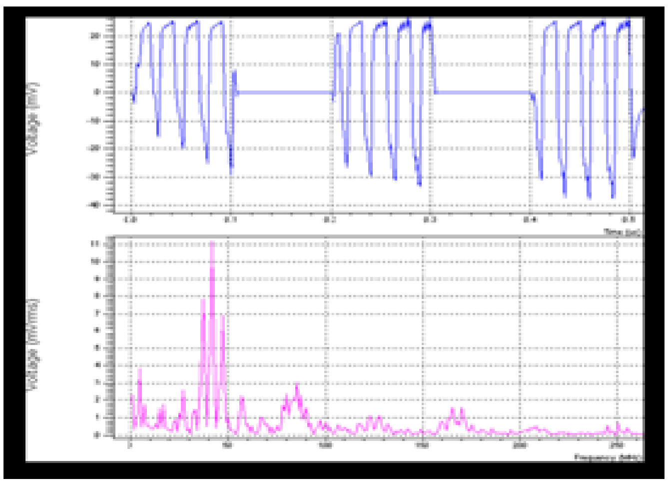


Figure.4.Output pulses generated through Resistive sensing UWB pulse generator

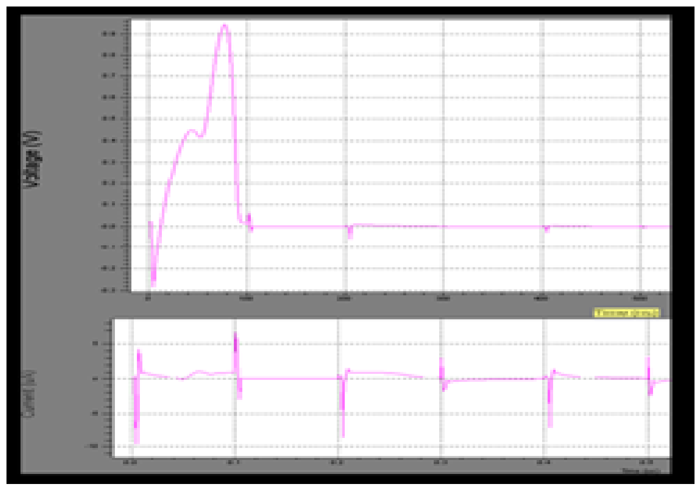


Figure.5.Out pulses generated by tunable pulse generator

Resistive Sensing UWB Pulse Generator: This section tells about the proposed pulse generator with the resistive sensing input. The change in the output voltage acquired by resistive sensing, instead of tuning the control voltage. The supply induced jitter reduction techniques reduces the jitter in the output. The power consumption decreased by compact number of stages in the buffer. A ring oscillator with an odd number of inverters stages. It translates the resistive changes according to the frequency variations. The pulse generator in Fig. 4 realised with the resistive sensing to control the voltage and frequency variations. In order to convey the resistive changes conforming to the oscillator control voltage, a simple interface circuit including M1, M2 and interface resistors considered. Since M1 and M2 functions in the saturation region, the input and the output transfer characteristic is linear. The phase noise and jitter are reduced by implementing the jitter reduction techniques in this circuit. The output generated by the pulse generator shown in fig. 5 simulated using tanner tools. The voltage attained is 22 mv, at 45 MHz frequency range with control input voltage of 1.5 v. The power consumption in the pulse generator with resistive sensing input is 0.15 µW. The output voltage acquired varies from 3.4v to 4.8v, accordingly the VCO frequency changes from 390 kHz to 550 kHz for the control voltage input varying from 1v to 6v. The resistive sensing pulse generator efficient than the previous work was simulated using matlab. This response increases the efficiency with reduced power consumption, which is used for UWB-WBAN application. The power output used for WBAN applications has power consumption less than 100µW. The simulation results show that the various power values got for different control voltage input which also satisfies the constraints of UWB technology is shown in the fig. 7.

Capacitive sensingUWB Pulse Generator: The capacitive sensing input circuit as shown in fig.6 is applied to pulse generator. This circuit is applied to terminate the parasitic capacitances related with the inverter. The ring oscillators used in telecommunication industry have phase noise. The main reason of the phase noise is the flicker noise of the inverters. This is overcome by insertion of a capacitor between the supply and the current as shown in fig.6. Therefore, the supply voltage controls the oscillation frequency. The pulse generator for C = 0.1pF is designed in fig.6 with control input voltage of 1.5 v. This design is simulated with tanner tools, it generates an output voltage of 0.5 mv at 250 MHz frequency. The output shown in fig.7 obtained in this design have power consumption of 0.132 µW.

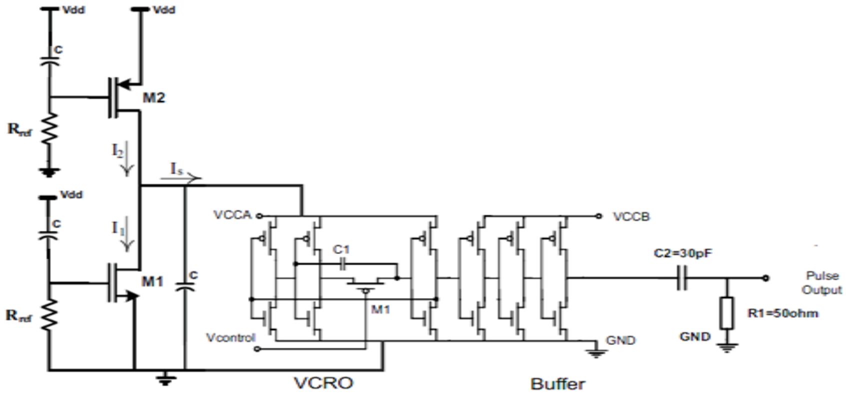
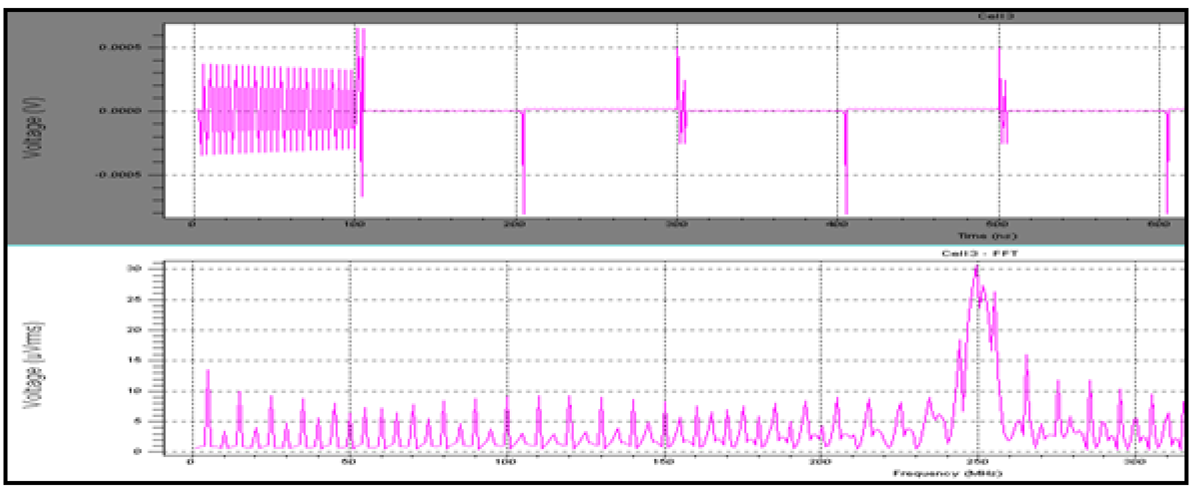


Figure.6.Capacitive Sensing UWB pulse generator



UWB Pulse generator

Fig.7. Output pulses generated through Capacitive sensing

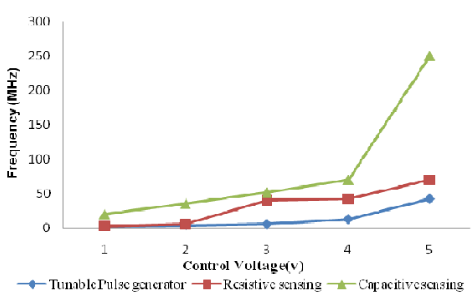


Fig.8. Pulse frequency Vs control voltage characteristics

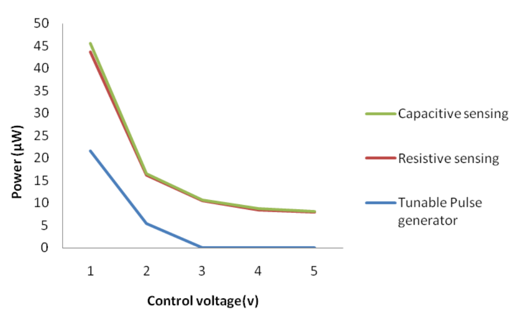


Fig.9. Power Vs control voltage characteristics

Figure.8.Pulse frequency Vs Control voltage characteristics

Figure.9.Power Vs Voltage characteristics

Measured Performances and Analysis: The simulation performed for different control voltage input values. The corresponding output voltage, power and frequency is obtained in both the designs. The performance metrics is analyzed and satisfies the FCC requirements of the UWB technology. The comparison of pulse generators design and UWB performance metrics are summarized.

Comparison of Pulse Generators Design: The pulse generators discussed above satisfy the FCC regulations of the frequency range from 0 to 960 MHz and 3.1 to 10.6 GHz spectrum range. The effective isotropic radiated power is kept below -41dBm/MHz. The comparison results are discussed in the following sections. It is obtained by simulation results of the pulse generator designs as shown in fig.8.The performance metrics are generated from the simulation of the three designs, are compared. The values obtained are also feasible for other UWB applications. The comparison of the pulse generators, according to the various parameters is shown in the table I. The simulation results of the pulse generator for frequency is shown in fig. 3. The control voltage of 1.5v is inputted, to obtain the output voltage obtained in the tunable pulse generator was 0.9v, with the pulse shaping circuit. The total power consumption in the design is 5.4 µW. Thus the tunable pulse generator is 72% efficient than the previous work, in terms of power. The resistive sensing pulse generator delivers the power consumption of 0.15µW, with the control voltage of 1.5v. In the frequency against the control voltage graph, the frequency variations infer that the pulse generators provides the optimum values. The simulation results shown in the fig. 5 obtained from the tanner tools. The output obtained is preferable for short range applications. The capacitive sensing pulse generator have power consumption of 0.132 µW, with pulse frequency of 250 MHz, for the control voltage of 1.5v. The output pulses shown in the fig. 7 obtained from the tanner tools. Fig.9 shows the comparison chart obtained from power values obtained against control voltage input.

Table.1.Comparision of UWB pulse generators

Parameters	Tunable pulse generator	Resistive sensing pulse generator	Capacitive sensing pulse generator
Pulse amplitude (V)	0.9 V	22 mv	0.5 mv
Frequency (MHz)	42	45	250
Power consumption (µW)	5.4	0.15	0.132

Table.2.Summary of UWB pulse generator

Parameters	Values
Pulse Amplitude (V)	0.5 mv
Control Voltage (V)	1.5V
Frequency (MHz)	250 MHz
Power Consumption	0.132 µW

Summary of UWB Pulse Generators: The table II provides the summary of the properties of the capacitive sensing pulse generator. With the different values of the control voltage, the corresponding changes in the frequency and power are obtained. The analysis obtained from the simulation results using tanner tools depicts that pulse generator with capacitive sensing input provides better performance and efficiency, with the reduced power consumption.

CONCLUSION

The low complexity UWB transmit only system designed with three configurations meets the power and frequency constraints of UWB technology. This design is applied to the WBAN applications. The capacitive sensing UWB pulse generator generates the total power of 0.132 µW, for the control voltage input of 1.5v. The pulse generator is applicable for all wireless applications like indoor communications, RF-ID, remote monitoring systems, etc. The jitter and phase noise reduced by jitter reduction techniques, to obtain an efficient UWB pulse generator.

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